THE GENERAL NAVIGATION FOR SEVERAL TRANSPORT MEANS

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Preface

This book covered the outline of the principals of general navigation to several means of transport. As an introduction, however, it serves to draw attention to the wide areas of integration within a complex industry of Transportation

The design of the contents follows the syllabus which was designed to the students of the international transport and logistic to let them know the science which affected the motion of several transport means.

The contents also have the relevance to developing transportation studies, leading to University Degrees and Diplomas with transport options.

The authors

The Contents

CHAPTER I

THE EARTH

CHAPTER I

The Earth:

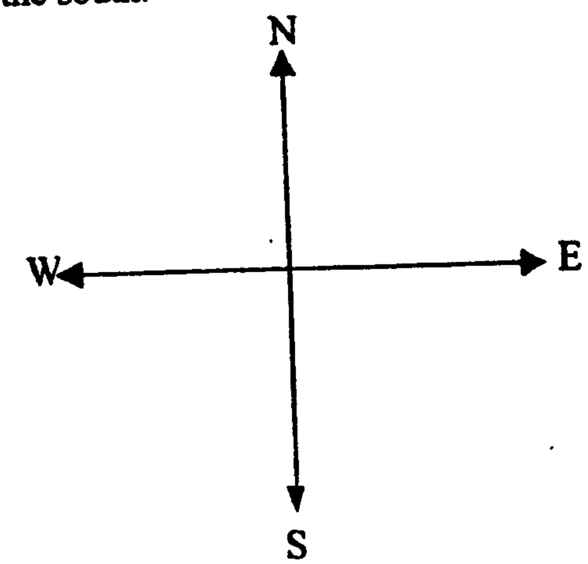
Many people may think that the earth is completely sphericaled, in fact it is not like that but it seemed that at her poles is slightly compressed forming ellipsoid shape. Since ancient time the scientists tried to realize the real shape of the earth and they found the followings: -

1- The sphericaled shadow of earth on the moon surface.
2- The endless edge of the horizon.
3- The high parts of things appear before the lower parts.
4- The time difference between countries.

After the great progress in mesile and earoplanes it became easier the approvals of the sphericaled apparition of the Earth. Many photos had been taken to the earth with different angles, and that could be on the television by receiving the satellite transmission.

The cardinal directions

The cardinal directions forming the principals methods in direction. The cardinal directions started from the earth motion infront the sun. The sun rises, starts from the East direction and the opposite direction is the west, the vertical direction to east – west direction will be as follows: -
The upper direction called the North and the opposite direction to the North will be the south.



The North and south poles:

The earth rotated around a certain axle once a day, forming the East and west phenomena. The apparent axle is not vertical but it declined with 23.5 degree approximately from the North direction. The apparent axle declination is constant, the upper pole called North Pole and the lower called South Pole.

Geodesy for any Navigators.

Geodesy may be defined as the science concerned with the exact positioning of points on the surface of the earth and the determination of the exact size and shape of the earth.

Coordinates:

The astronomic latitude is the angle between the plumb line at a station and the plane of the celestial equator. The geographic latitude is a general term used to show that the earth is divided into 180 latitude, 90° latitude north while the other 90 latitude is south. These latitude lines are paralleled to the equator. The equator latitude is the main latitude to the earth. The equator devided the earth into two directions, the first forming north direction and the second direction is south. The equator forming the base line of measuring, so that, the equator is 0 degree. From this equator to the north pole is scaled into 90 degree north direction and from equator to 90 degree south direction.

The astronomic longtitude is the angle between the plane of the celestial meridian at a station and the plane of the celestial meridian at Greenwhich.

The greenwhich longtitude is the main geographical longtitude at which the direction could be to east direction or to the west direction.

The advantages of the geographical latitude and longtitude are on the following lines: -

1 – Showing the climatology conditions at anywhere on the earth.

2 – To calculate the exact time from one place to another.

3 – To identify any location on the earth.

4 – It is used in chart projections.

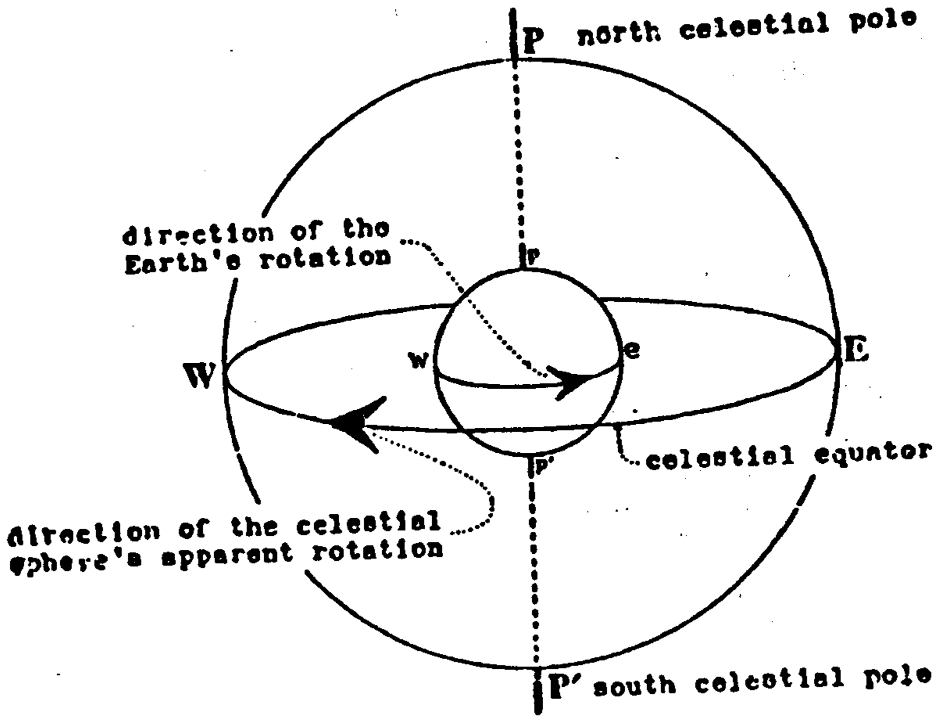
5 – Facilitate the motion of any transport modes such as, trucks, vessels,

Aeroplanes, trains, cars.....

The Celestial Sphere

To an observer on the Earth, the sky has the appearance of an inverted bowl, so that the stars and other heavenly bodies, irrespective of their actual distance from the Earth, appear to be situated on the inside of a sphere of immense radius described about the Earth as centre. This is called the *celestial sphere*.

The Celestial poles. These are the points—P and P' in the following figure –in which the Earth's axis, if produced, would cut the celestial sphere.



The Celestial Equator. This is the great circle in which the plane of the Earth's equator cuts the celestial sphere.

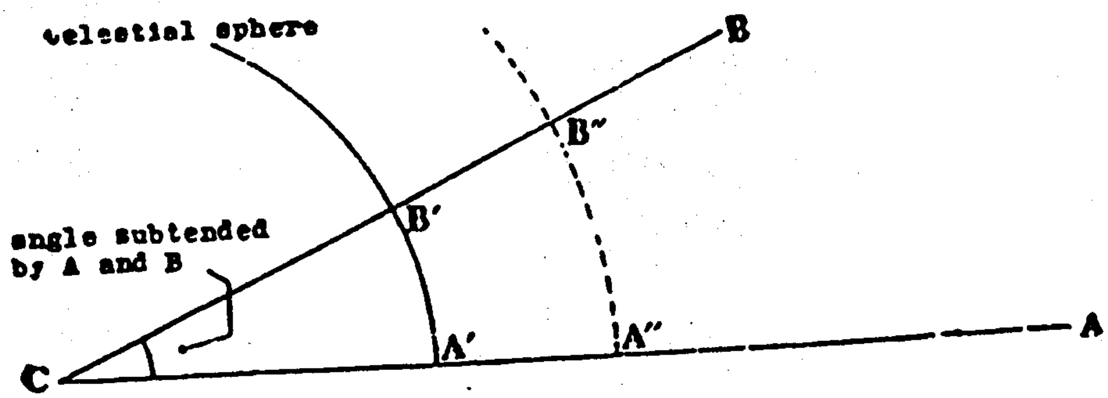
Apparent motion of the celestial sphere

Within the celestial sphere, which is fixed, the Earth rotates about its axis, turning eastward, but an observer on the Earth is not aware of this rotation unless he watches the movement of objects in no way connected with the Earth, just as a passenger in a railway train is not aware of its forward movement unless he watches the neighboring countryside slipping backward across the carriage window. The celestial sphere therefore appears to rotate westward, and for this reason the sun and the stars appear to rise east of, and to set west of, the observer's meridian.

Angular distance between the stars

The appearance of the stars on the celestial sphere conveys no idea of their actual distances from the Earth.

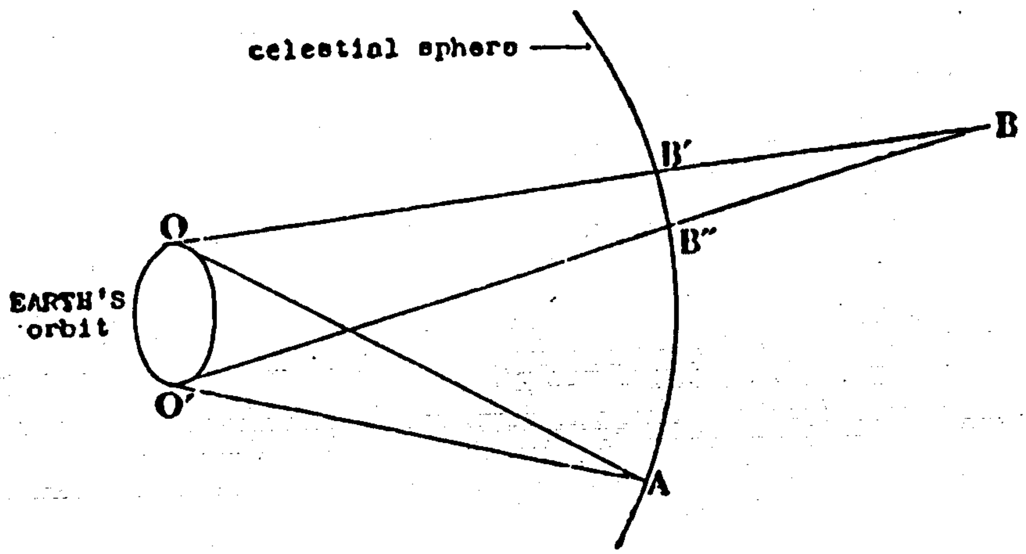
The star A, for example, in the following figure, may be ten times more remote than the star *B*, but the angle which the two subtend at C, the Earth's centre, is the same whether the stars are assumed to be at *A'* and



B' or A'' And B''. To an observer on the Earth, the distance between them (or between any other heavenly bodies) is thus an angular distance, and he can deal with all problems involving the measurement of that distance by the methods of spherical trigonometry.

The actual distances, moreover, are so great that any movement which the stars have in space is lost to the casual observer on the Earth. Within ordinary limits of time the angle ACB thus remains constant except for the small variation which results from the Earth's orbital motion.

The following figure, which is much exaggerated for the sake of clarity, shows how this variation can occur.

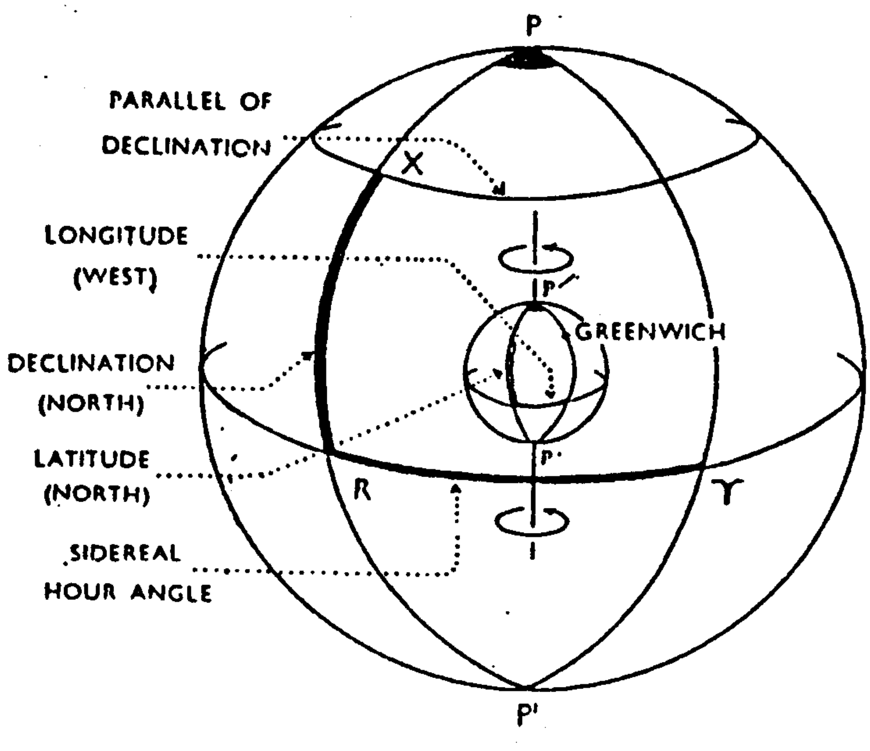


A and B are two stars, the position of A being considered fixed in the celestial sphere. When the Earth is at O, the angle subtended by these stars is AOB, and B appears on the celestial sphere at B', but when the Earth is at O', the other extremity of its orbit, the angle subtended is $AO'B$, and B appears on the celestial sphere at B''. The position of B

therefore varies in relation to the position of A. This variation, however, is usually negligible because the length OO' is negligible in comparison with the distances of most stars.

Apparent path of the Sun in the celestial sphere

When a heavenly body such as the Sun is comparatively close to the Earth, it's position in the celestial sphere changes considerably during a year relative to the Earth and a distant star lying in the plane of the Earth's orbit. The choice of such a star gives a fixed direction in space from which angles can be
Green which meridian lie in the same plane as and also directly beneath, the meridian through the First Point of Aries, as in the following figure.



EXAMPLE 1

What is the declination of Mars on 2 nd January, 1952, at *G.M.T.* 18h 47m 23s?

From the daily page for 2 nd January :

Declination at 18h = 6° 44'.2S. d = 0'.5.

From the interpolation table for 47m (second of G.M.T. do not matter here):

Corr^n for d = 0'.5 is + 0'.4 (positive because the declination is increasing).

Therefore declination at 08h 47m 23s = 6° 44'.2 + 0'.4
= 6° 44'.6S.

The Moon's declination varies less uniformly and more quickly than that of the Sun and Planets an, although the declination is tabulated for every hour of G.M.T., in the same way, the hourly difference has to be given for every hour. The correction is obtained from the interpolation table for the minutes of G.M.T. in the same way as above.

EXAMPLE 2

What is the declination of the Moon at G.M.T. 18h 47m 23s on 2nd January, 1952?

Declination at 18h	= 0° 54'.0S.	d = --16'.2
Corr^n	= - 12'.8	
Declination at 18h 47m 23s	= 0° 41'.2	

Parallel of Declination

This corresponds to a parallel of latitude and is a small circle on the celestial sphere, the plane of which is parallel to the plane of the celestial equator.

Polar Distance

This is the angular distance of a body from the elevated pole; the pole, that is, above the observer's horizon. It is *PX* in the above figure, if the observer is assumed to be in the north latitude.

When the elevated pole and the declination have the same names, the polar distance is clearly (90° -- declination). When they have opposite names, it is equal to (90° + declination).

Geographical Position

If a line is drawn from a heavenly body to the Earth's centre, the point where this line cuts the Earth's surface is called the *geographical position* of the body.

XC in the following figure is such as line, and *x* is the geographical position of *X*. To an observer at *x*, the body would thus appear to be exactly overhead. That is, the body would be at the observer's zenith.

The Observer's Zenith

This is the point where a straight line from the Earth's centre passing through the observer's position cuts the celestial sphere. The declination of the zenith (*ZQ* in above figure) must therefore be equal to the observer's latitude, (*Oq*).

The Celestial, or Rational, Horizon

The great circle on the celestial sphere, every point of which is 90° from the observer's zenith, is known as the *celestial*, or *rational, horizon.*

A plane through the centre of the Earth at right angles to the observer's radius, *CO*, would cut the celestial sphere in this great circle. The celestial horizon therefore divides the celestial sphere into hemispheres, the upper one of which, containing *Z*, is known as the visible hemisphere because, subject to certain small adjustments described in the next chapter, all heavenly bodies in this half of the celestial sphere are visible to the observer at *O*. Heavenly bodies in the lower hemisphere cannot be seen.

The Observer's Meridian

This is the celestial meridian which passes through the observer's zenith –*PZQSP'* in the above figure. The meridian *PNQ'Z'P'* differs from it by 180° in sidereal hour angle.

The points, *N* and *S*, in which these two meridians cut the celestial horizon are the north and south points, the north point being the one nearer the north pole.

TIME

Introduction.—Time serves to regulate affairs aboard ship, as it does ashore. But to the navigator, it has additional significance. It is not enough to know *where* the ship is, was, or might be located in the future. The navigator wants to know more the various positions were or can reasonably be expected to be occupied. Time serves as a measure of progress. By considering the time at which a ship occupied various positions in the past, and by comparing the speed and various conditions it has encountered with those anticipated for the future, the skillful navigator can predict with reasonable accuracy the time of arrival at various future positions. Time can serve as a measure of safety, for it indicates when a light or other aid to navigation might be sighted, and if it is not seen by a certain time, the navigator knows he has cause for concern.

To the celestial navigator, time is of added significance, for it serves as a measure of the *phase* of the earth's rotation. That is, it indicates the position of the celestial bodies relative to meridians on the earth. Until an accurate *measure* of time became available at sea, longitude could not be found.

Very small *intervals* of time are used in certain electronic navigational aids, such as radar and Loran.

Whatever the type of navigation, a through mastery of the subject of time is important to the navigator.

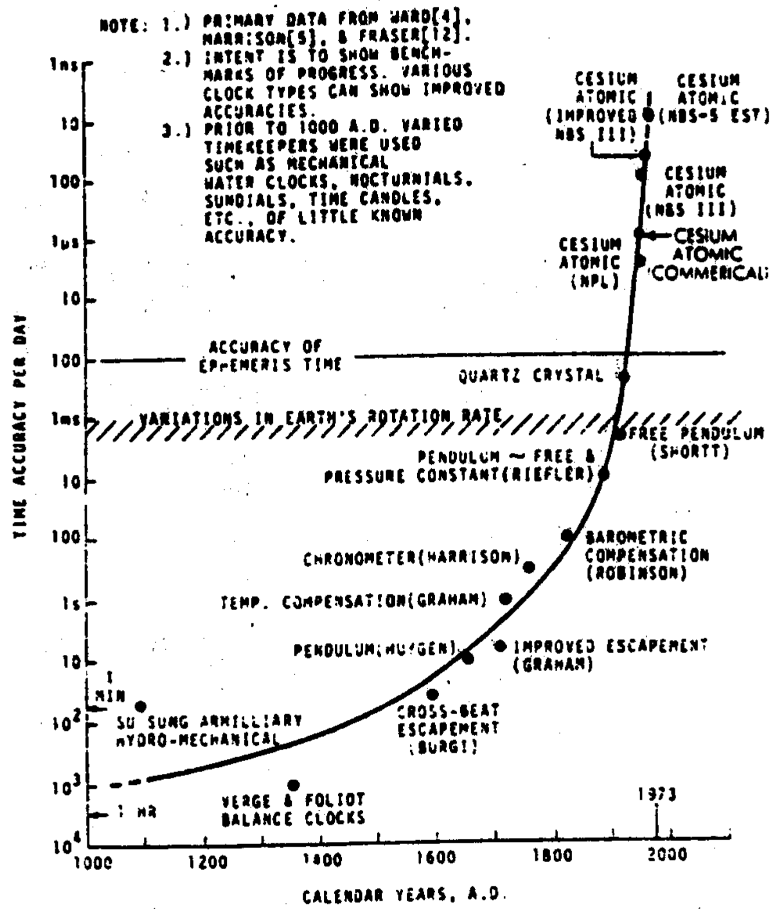
The four independent base units of measurement currently used in science are length, mass, time, and temperature. It is true that, except for fields of science such as cosmology, geology, and astronomy, time interval is the more important time concept, and date (astronomical) is of much less importance to the rest of science. This is true because the "basic laws" of physics are differential in nature and only involve small time intervals. In essence, physical "laws" do not depend upon when (i.e., the date) they are applied.

Based on these laws and extensive experimentation, scientists have been able to demonstrate that frequency can be controlled and measured with the smallest percentage error of any physical quantity. The

frequency of a periodic phenomenon is the number of cycles of this phenomenon per unit of time (i.e., per second). The name of the unit of frequency is the **hertz (Hz)** and is identical to a cycle per second (cps). Since most clocks depend upon some periodic phenomenon (e.g., a pendulum) in order to "keep time", and since one can make reliable electronic counters to count the "swings" of the periodic phenomenon, we can construct clocks with timekeeping accuracy (rate accuracy) equal to the accuracy of the frequency standard. Today's most precise and accurate clocks incorporate a cesium atomic beam as the "pendulum" of the clock.

Clocks and timekeeping.—In early times, the location of the sun in the sky was the only reliable indication of the time of day. Of course, when the sun was not visible, one was unable to know the time with much precision. People developed devices (called clocks) to interpolate between checks with the sun. The sun was sort of a "master clock" that could be read with the aid of a sundial. An ordinary clock, then, was a device used to interpolate between checks with the sun. The gain in accuracy of the different clock devices over a period of years is shown in the following figure. (Timekeeping has shown nearly 10 orders of magnitude improvement within the last 6 centuries with about 6 orders occurring within 70 years of the 20th century). Thus, a clock could be a "primary clock" like the position of the sun in the sky, or it could be a secondary clock and only interpolate between checks with the primary clock or time standard. Historically, some people have used the word "clock" with the connotation of a secondary time reference, but today this usage would be too restrictive.

When one thinks of a clock, it is customary to think of some kind of pendulum or balance wheel, a group of gears, and a clock face. Each time the pendulum completes a swing, the hands of the clock are moved a precise amount. In effect, the gears and hands of the clock "count" the number of swings of the pendulum. The face of the clock, of course, is not marked off in the number of swings of the pendulum but rather in hours, minutes, and seconds.



Progress in timekeeping accuracy

One undesirable characteristic of pendulum-type clocks is that no two clocks ever keep exactly the same time. This is one reason for looking for a more stable "pendulum" for clocks. In the past, the most stable "pendulums" were found in astronomy. Here one obtains a significant advantage because only one universe exists—at least for observation purposes, and time defined by this means is available to anyone—at least in principle. Thus, one can obtain a very reliable time scale which has the property of universal accessibility. In this chapter, time scale (art.1804) is

used to refer to a conceptually distinct method of assigning dates to events.

In a very real sense, the pendulum of ordinary, present-day electric clocks is the electric current supplied by the Power Company. In the United States the power utilities generally synchronize their generators to the National of Standards (NBS) low frequency broadcast, WWVB. Thus, the right number of pendulum swings occur each day. Since all electric clocks which are powered by the same source have, in effect, the same pendulum, these clocks do not gain or lose time relative to each other; i.e., they run at the same rate. Indeed, they will remain fairly close to the time as broadcast by WWVB (±5 seconds) and will maintain the same time difference with respect to each other (± 1 millisecond) over long periods of time.

It has been known for some time that atoms have characteristic resonances or, in a loose sense, "characteristic vibrations". The possibility therefore exists of using the "vibrations of atoms" as pendulums for clocks. Presently, microwave resonances (vibrations) of atoms are the most precisely determined and reproducible physical phenomena that man has encountered. A clock which uses "vibrating atoms" as a pendulum will generate a time scale more uniform than even its astronomical counterparts.

But due to intrinsic errors in any actual clock system, atomic clocks drift relative to other similar clocks. Of course, the rate of drift is much smaller for atomic clocks, but nonetheless real and important. The attribute of universal accessibility for atomic time is accomplished by coordination between laboratories generating atomic time.

Basic concepts of time.—One can use the word "time" in the sense of date.(By "date" we mean a designated mark or point on a time scale). One can also consider the concept of time interval or "length" of time between two events. The difference between these concepts of date and time interval is important and has often been confused in the single word "time".

The *date* of an event on an earth-based time scale is obtained from the number of cycles (and fractions of cycles) of the apparent sun counted from some agreed-upon origin. Similarly, atomic time scales time scales

are obtained by counting the cycles of a signal in resonance with certain kinds of atoms.

The word "epoch" is sometimes used in a similar manner to the word "date". However, dictionary definitions of epoch show gradations of meanings such as time duration, time instant, or a particular time reference point, as well as a geological period of time. Thus, epoch often simultaneously embodies concepts of both date and duration. Because of such considerable in the word "epoch", its use in this volume will be restricted to a time instant.

Another aspect of time is that of *simultaneity*; i.e., coincidence in time of two events. For example, we might synchronize clocks upon the arrival of portable clocks at a laboratory. Here we introduce an additional term, *synchronization*, which implies that the two clocks are made to have the same reading in some frame of reference. Note that the clocks need not be synchronized to an absolute time scale. As an example, two people who wish to communicate with each other might not be critically interested in the date, they just want to be synchronized as to when they use their communications equipment.

Time scales.—A system of assigning dates to events is called a **time scale.** The apparent motion of the sun in the sky constitutes one of the most familiar time scales but is certainly not the only time scale. Note that to completely specify a date using the motion of the sun as a time scale, one must count days (i.e., make a calendar) from some initially agreed-upon beginning. In addition (depending on accuracy needs) one measures the fractions of a day (i.e., "time of day") in hours, minutes, seconds, and maybe even fractions of seconds. That is, one counts cycles (and even fractions of cycles) of the sun's daily apparent motion around the earth.

Fundamental kinds of time.—There are three fundamentally different kinds of time. These are time based on the rotation of the earth on its axis; time based on long term observations of the annual revolution of the earth around the sun; and time based on transitions in the atom.

Time based on the rotation of the earth on its axis has several forms, all of which are related to each other by rigorous formulae or appropriate tables. These forms are the various sidereal times, mean and apparent, and solar times, mean and apparent.

Time defined by the daily rotation of the earth with respect to the equinox or first point of Aries is known as sidereal time. The sidereal time is numerically measured by the hour angle of the equinox, which represents the position of the equinox in the daily rotation. The period of one rotation of the equinox in hour angle, between two consecutive upper meridian transits, is a **sidereal day**; it is divided into 24 sidereal hours, reckoned from 0^h at upper transit which is known as **sidereal noon**. The true equinox is at the intersection of the true celestial equator of data with the ecliptic of date; the time measured by its daily rotation is **apparent sidereal time.** The position of the true equinox is affected by the nutation of the axis of rotation of the earth; and the nutation consequently introduces irregular periodic inequalities into the apparent sidereal time and the length of the sidereal day. The time measured by the daily motion of the mean equinox of date, which is affected only by the secular inequalities due to the precession of the axis, is mean sidereal time. The maximum difference between apparent and **mean sidereal times** is only a little over a second, and its greatest daily change is a little more than a hundredth of a second Because of its variable rate, apparent sidereal time is used by astronomers only as a measure of epoch; it is not for time interval. **Mean** sidereal time is deduced from apparent sidereal time by applying the equation of equinoxes.

Universal Time (UT) is a particular case of the measure known in general as **mean solar time**. Universal Time is the mean solar time on the Greenwich meridian. reckoned in days of 24 mean solar hours beginning with 0^h at midnight. Universal Time and sidereal time are rigorously related by a formula so that if one is known the other can be found. The ratio of the mean solar day to the mean sidereal day is 1.0027379093, and the equivalent measures of the length of the day are:

Mean sidereal day .... $23^h56^m04^s.09054$ of mean solar time.
Mean solar day .... $24^h03^m56^s.55536$ of mean sidereal time.

Universal Time, in principle, is determined by the *average* rate of the apparent daily motion of the sun relative to the meridian of Greenwich; but in practice the numerical measure of Universal Time at any instant is computed from sidereal time.

Universal Time is the standard in the application of astronomy to navigation. Observations of Universal Time are made by observing the time of transit of stars.

The Universal Time determined directly from astronomical observations is denoted UT0. Since the earth's rotation is nonuniform, corrections must be applied to UT0 to obtain a more uniform time. This more uniform time is obtained by correcting for two known periodic motions.

One motion, the **polar motion** (the motion of the geographic poles), is the result of the axis of rotation continuously moving with respect to the earth's crust. The corrections for this motion are quite small (±15 milliseconds for Washington. D.C.). On applying the correction to UT0, the result is **UT1**, which is the same as Greenwich mean time **(GMT)** used in celestial navigation.

The second known periodic motion is the variation in the earth's speed of rotation due to winds, tides, and other phenomena. As a consequence, the earth suffers an annual variation in its speed of rotation of about ±30 milliseconds. When UT1 is corrected for the mean seasonal variations in the earth's rate of rotation, the result is **UT2.**

Although UT2 was at one time believed to be a uniform time system, it was later determined that there are secular variations in the earth's rate of rotation, possibly caused by random accumulations of matter in the convection core of the earth. Such accumulations would change the earth's moment of inertia and thus its rate of rotation.

The second fundamental kind of time, **Ephemeris Time (ET),** now known as **dynamical time,** is, by definition, a uniform time system. Ephemeris Time is the uniform measure of time defined by the law of dynamics and determined in principle from the orbital motions of the planets, specifically the orbital motion of the earth as represented by Newcomb's *Tables of the Sun.* Ephemeris Time is the measure of time in which Newcomb's *Tables of the Sun* agree with observation. Ephemeris Time is time based on the ephemeris second defined as 1/31556925.9747 of the tropical year for 1900 January 0^d12^h ET. The ephemeris day is 86,400 ephemeris seconds. The ephemeris second is a fundamental invariable unit of time.

The Ephemeris Time at any instant is obtained from observation by directly comparing observed positions of the sun, moon, and planets with gravitational ephemerides of their coordinates; observations of the moon are most effective and expeditious for this purpose. Ephemeris Time is used by astronomers in the fundamental ephemerides of the sun, moon, and planets, but is not used by navigators.

The third fundamental kind of time, **Atomic Time (AT)**, is based on transitions in the atom.

The basic principle of the **atomic clock** is that electromagnetic waves of a particular frequency are emitted when an atomic transition occurs. The frequency of the **cesium beam clock** was found to be 9,192,631,770 cycles per second of Ephemeris Time in an experiment conducted jointly by the National Physical Laboratory, Teddington, England, and the U. S. Naval Observatory during 1955-1958.

In 1967 the atomic second was defined by the Thirteenth General Conference on Weights and Measures as the duration of 9.192.631.770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of the cesium atom 133. This value was established to agree as closely as possible with the ephemeris second. Thus, the atomic second became the unit of time in the **International System of Units (SI).**

UT2 and A1, the atomic time scale established by the U.S. Naval Observatory in 1958, were identical on January 1,1958. To the accuracy currently available, A1 and ET differ only by a constant such that $ET - A1 = 32^s.18$.

The advent of atomic clocks, which have accuracies better than 1 part in 10^{10} led in 1961 to the coordination of time and frequency emissions of the U. S. Naval Observatory and the Royal Greenwich Observatory. The master oscillators controlling the signals were calibrated in terms of the cesium standard (A1) and corrections determined at the U. S. Naval Observatory and the Royal Greenwich Observatory were made simultaneously at all transmitting stations. Because of the divergence of the astronomical and atomic time scales due to the unpredictable variations in the earth's rotation, the time emissions were adjusted by applying a frequency offset to the oscillator so that the rate defined by the

timing pulses was in general agreement with UT2. If, in spite of this departure of the time signals from UT2 became unacceptable, the epoch of the signals was adjusted by 100 millisecond steps. These adjustments kept the transmitted time synchronized with the rotation of the earth within a tolerance of $0^s.1$. This system became known as **Coordinated Universal Time (UTC)** and was accepted by many authorities following its formal recommendation in 1961 by the International Astronomical Union **(IAU)** and in 1963 by the International Radio Consultative Committee**(CCIR)**,a committee of the International Telecommunications Union **(ITU)** which controls international coordination of time signal transmission.

In February 1970 at the Plenary Assembly of the ITU, it was agreed that commencing January 1, 1972, the use of frequency offsets would be discontinued and that all time signal transmissions would be based strictly on the internationally adopted definition of the second. The ITU also agreed that the coordinated time transmission based on the atomic second be maintained in approximate agreement with UT1 by stepping the transmitted time one whole second whenever necessary.

In accordance with the implementation resolutions of the IAU, the new system was inaugurated January 1, 1972, using the second defined in terms of an **International Atomic Time (TAI)** scale (art. 1806) as the unit of time and UT1 as the astronomical reference, Beginning at this time, UTC was then maintained in approximate agreement with UT1 by step adjustments **(leap seconds)** as directed by the Bureau International de l'Heure (BIH).

At the end of 1971, before the new system was inaugurated, there was a difference of almost 10 seconds between TAI and UTC. In order that this difference be an integral number of whole seconds (in this case 10^s) a special negative adjustment of approximately 0.108^s was made in accordance with BIH directive so that the reading on the UTC scale was 1 January 1972, $00^h00^m00^s$ at the instant the TAI scale was 1 January 1972, $00^h00^m10^s$.

International Atomic Time (TAI) scale.---In October 1971, the General Conference on Weights and Measures endorsed the Bureau

International de l'Heure (BIH) atomic time scale as the International Atomic Time (TAI) scale defined as follows:

"International Atomic Time is the time reference coordinate established by the Bureau International de l'Heure on the basis of the readings of atomic clocks functioning in various establishments in accordance with the definition of the second, the SI Unit (International System of Units) of time".

The Atomic Time (AT) scales maintained in the United States by the National Bureau of Standards and the U. S. Naval Observatory constitute approximately 37½ percent of the stable reference information used in maintaining a stable TAI scale by the BIH.

Time interval and time scales.—One should note sources of confusion which can exist in measurement of time and in the use of the word "second". Suppose that two events occurred at two different dates. For example the dates of these two events were 15 December 1970, $15^h30^m00^s.000000$ UTC and 15 December 1970, $16^h30^m00^s.000000$ UTC. At first thought one would say that the time interval between these two events was exactly 1 hour = 3600.000000 seconds, but this is *not* true.(The actual interval was longer by about 0.000108 seconds [3600 seconds $\times 300 \times 10^{-10}$]. Refer to table 1807.) Recall that the UTC time scale (like all the UT scales and the ET scale) was not defined in accordance with the definition of the interval of time, the second. Thus, one cannot simply subtract the dates of two events as assigned by the UTC scale (or any UT scale or the ET scale) in order to obtain the precise time interval between these events. Historically, the reason behind this state of affairs is that navigators needs to know the earth's position (i.e., UT1)—not the duration of the second. Yet, many scientists need to know an exact and reproducible time interval. Note that this might also be true of the new UTC system if the particular time interval included one or more leap seconds.

It is also confusing that the dates assigned by the UT, ET, and UTC scales involve the same word as the unit of time interval, the second. For accurate and precise measurements, this distinction can be extremely important.

Solar Time.—The basis of time measurement in celestial navigation is the period of rotation of the earth. This period is not quite constant; it is subject to variations which may reach a few milliseconds per day. These variations will be disregarded initially; the earth will be conceived as rotating at a constant rate.

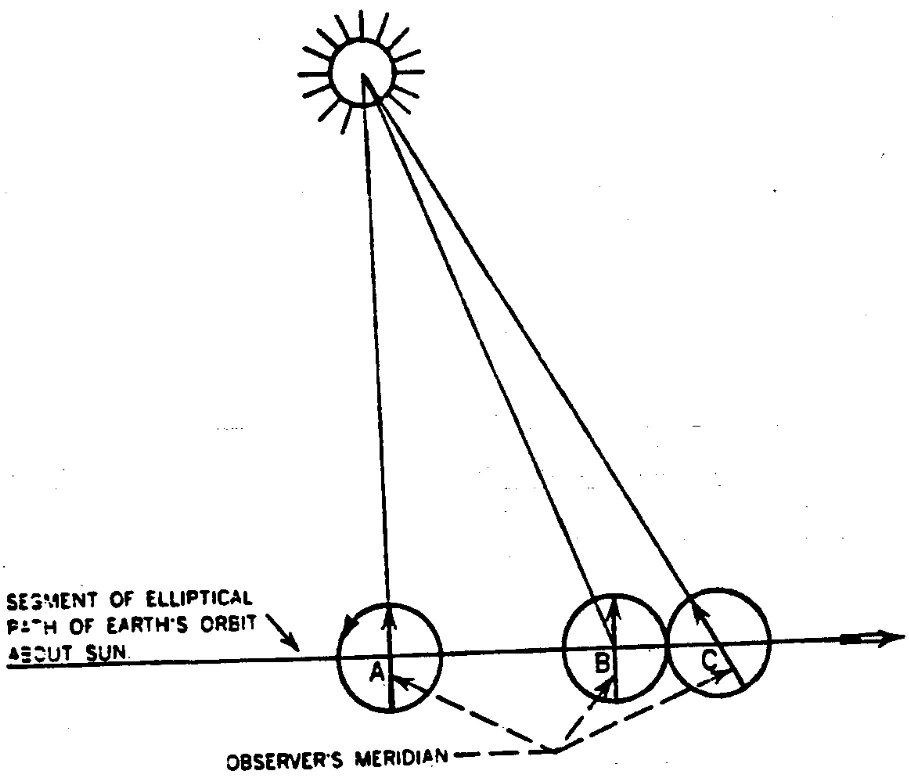
Year	Offset rate of UTC in parts per 10^{10}
1960	−150
1961	−150
1962	−130
1963	−130
1964	−150
1965	−150
1966	−300
1967	−300
1968	−300
1969	−300
1970	−300
1971	−300
1972 → future	0

Frequency offsets of UTC from 1960 to 1972

The earth's rotation causes the sun and other celestial bodies to appear to cross the sky from east to west each day. If a person located on the earth's equator measured the time interval between two successive transits overhead of a very distant star, he would thereby measure the period of the earth's rotation. If he then made similar measurements on the sun instead of a star, he would obtain a result about 4 minutes longer than before. This difference is due to the earth's motion around the sun, which continuously changes the apparent place of the sun among the stars. Thus, during the course of a day the sun appears to move a little to the east among the stars so that the earth must rotate on its axis through

more than 360° in order to bring the sun overhead again. Of course this apparent eastward movement of the sun cannot be observed directly.

If the sun is on the observer's meridian when the earth is at point *A* (See the following Figure) in its orbit around the sun, it will not be on the observer's meridian after the earth has rotated through 360° because the earth will have moved along its orbit to point *B*. Before the sun is again on the observer's meridian, the earth must turn still more on its axis. The sun will be on the observer's meridian again when the earth has moved to point *C* in its orbit. Thus, during the course of a day the sun appears to move eastward with respect to the stars.



Apparent eastward movement of the sun with respect to the stars.

Even if the earth did not rotate on its own axis, the sun would rise and set once during the year because of the earth's orbit around it. The stars, however, are not within the earth's orbit. Since they are generally more than a million times as distant as the sun, their apparent positions are only very slightly affected by the earth's orbital motion. The apparent positions of the stars are commonly reckoned with reference to an imaginary point called the vernal equinox, which is the intersection of the celestial equator and the ecliptic. The sun is at the vernal equinox at the beginning of spring, when it passes over the equator on its apparent journey northward. The period of the earth's rotation measured with respect to the vernal equinox is called a sidereal day. The period with respect to the sun is called an apparent solar day.

With the sun moving eastward among the stars so that the difference between the apparent solar and sidereal day is about 4 minutes of time, on any night a star will rise about 4 minutes earlier than on the previous night. Thus, the celestial sphere appears to shift westward about 1° each night. The complete shift through 360° is associated with the year, the period of one revolution of the earth around the sun. By the calendar, one year is 365 days duration for a common year and 366 days for a leap year. A leap year is any given year divisible by 4, unless it is a century year, which must be divisible by 400 to be a leap year. Thus, 1900 was not a leap year, but 2000 will be. This calendar, now in general use, is called the **Gregorian calendar.**

When measuring time by the rotation of the earth, the time is apparent solar time if the apparent (real) sun is used as the celestial reference.

Use of the apparent sun as a celestial reference for time results in time of nonconstant rate for at least three reasons. First, revolution of the earth in its orbit is not constant. Second, motion of the apparent sun is along the ecliptic, which is tilted with respect to the celestial equator, along which time is measured. Third, rotation of the earth on its axis is not constant. The effect due to this third cause is extremely small.

For the various forms of mean solar time, the apparent sun is replaced by a fictitious **mean sun,** conceived as moving eastward along the celestial equator at a uniform speed equal to the average speed of the apparent sun along the ecliptic, thus providing a nearly uniform meaure of

time equal to the approximate average apparent time. The speed of the mean sun along the celestial equator is taken as 15° per hour of mean solar time.

Equation of time.—Mean solar time, or mean as it is commonly called, is sometimes ahead of and sometimes behind apparent solar time **(sundial time)**. The difference, which never exceeds about $16^m.4$, is called the equation of time **(Eq . T.)**

By one convention, the equation of the time interval which must be added algebraically to the mean time to obtain apparent time. This convention is used here.

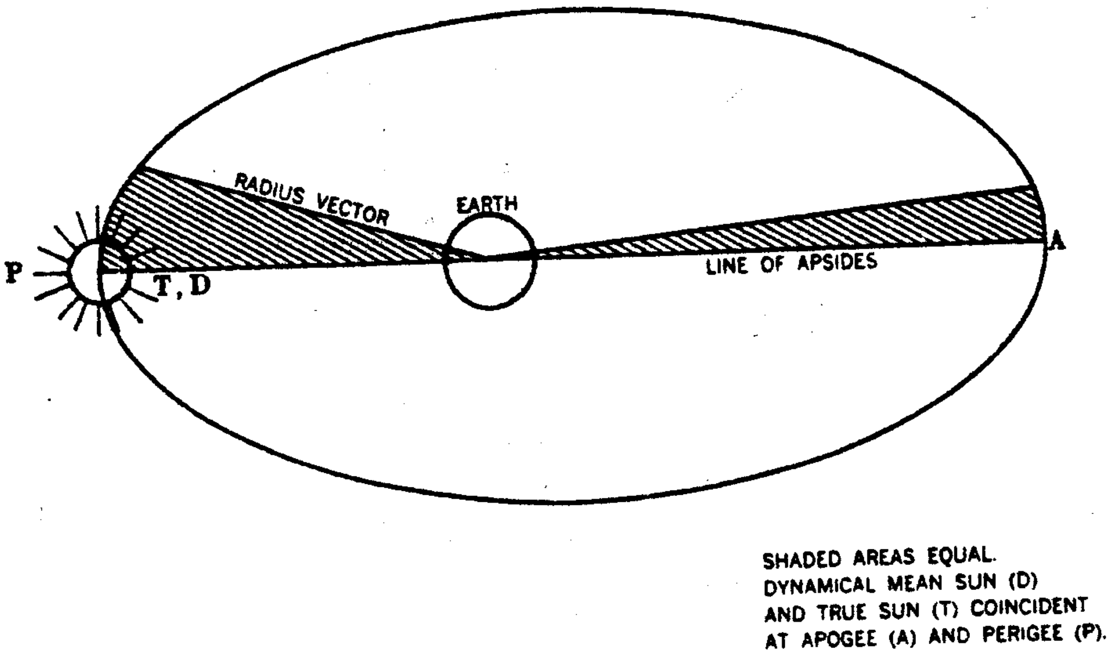
In accordance with Kepler's second law (art. 1407), the speed of the earth in its elliptical orbit around the sun varies with the changing distance between the two bodies. The earth moves faster at perihelion than it does at aphelion. Consequently, as seen from the earth the sun appears to move faster in January than it does in July. Even if the earth's orbital speed were uniform, the hour angle of the sun would still change at a variable rate because the sun as observed from the earth appears to move in the plane of the ecliptic, which is inclined at an angle of about 23°27' to the plane of the celestial equator.

In deriving the value of the equation of time it is simpler to consider the contributions of the ellipticity and obliquity of the apparent orbit of the sun about the earth separately. In considering the ellipticity and obliquity contributions separately, it is convenient to introduce a second fictitious sun. This second sun, known as the dynamical mean sun, is conceived to move eastward along the ecliptic at the average rate of the apparent (true) sun. The dynamical mean sun and the apparent sun occupy the same position when the earth is at perihelion (or the sun is at perigee when using the concept that the sun orbits the earth). The dynamical mean sun and the mean sun, or **astronomical mean sun** as it is sometimes called, occupy the same position at the time of the vernal equinox.

That part of the equation of time due to the ellipticity of the orbit and known as the **eccentricity component** is the difference, in mean solar time units, between the hour angles of the apparent (true) sun and the dynamical mean sun. It is also the difference in the right ascensions of

these two suns. That part of the equation of time due to the obliquity of the orbit is the difference in units of mean solar time, between the hour angles of the dynamical mean sun and the astronomical mean sun. It is also that difference in the right ascensions of these two suns.

The following figure illustrates the apparent orbit of the sun about the earth. In accordance with Kepler's second law the radius vector sweeps through equal areas in equal time intervals. Therefore, the angular velocity of the true sun is greatest at perigee. With the true sun *T* and the dynamical mean sun *D* occupying the same position at perigee *P* around 1 January, following perigee the true sun moves ahead of the dynamical mean sun which is moving eastward along the ecliptic at the average rate of the true sun. The maximum separation of about 2°(8 minutes) occurs about 1 April. Because of Kepler's second law, the dynamical mean sun and the true sun must be in coincidence again at apogee *A* about 1 July. The time for the true sun to move from perigee to apogee is equal to the time for the true sun to move from apogee to perigee. Since the dynamical mean sun moves at the average rate of the true sun, the time to complete the orbit of the ecliptic is equal to the time required for the true sun to



Apparent orbit of the sun about the earth.

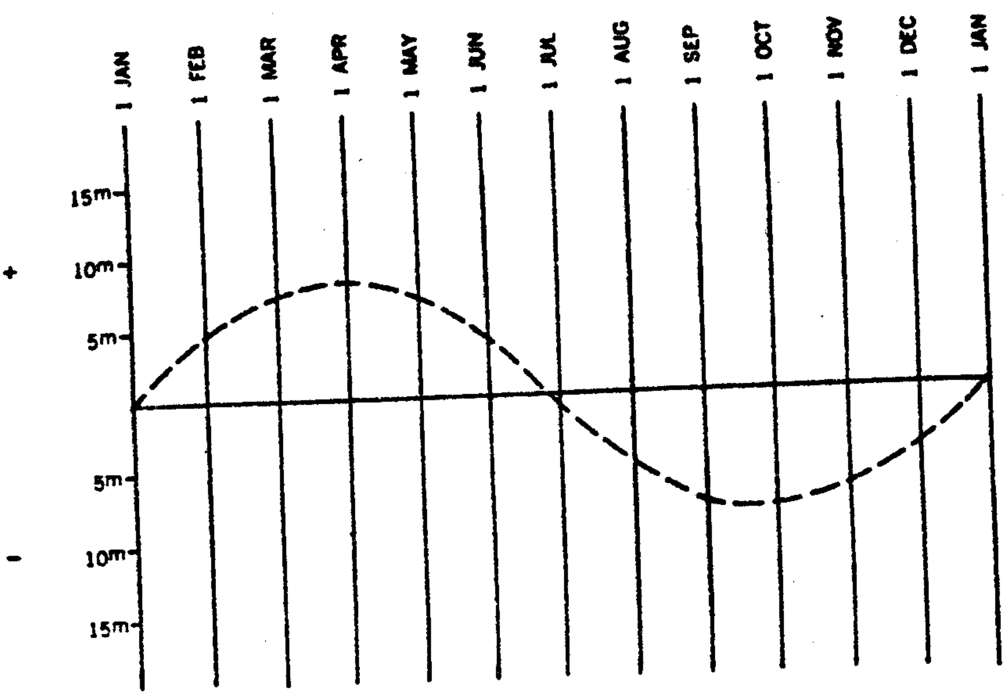
complete the same orbit. Since the line of apsides bisects the sun's apparent orbit, it follows that the time required for the dynamical mean sun to complete half the orbit is the same as that required for the true sun to complete half the orbit. Therefore, the dynamical mean sun and the true sun occupy the same position at apogee.

With the true sun and the dynamical mean sun occupying the same position at apogee and with the angular velocity of the true sun being least at apogee, following apogee the dynamical mean sun moves ahead of the true sun. The maximum separation of about 2° (8 minutes) occurs about 1 October. The two suns are again coincident at perigee about 1 January.

The eccentricity component of the equation of time is shown in the above figure. The obliquity component of the equation of time can now be found by comparing a dynamical mean sun moving uniformly along the ecliptic with an astronomical mean sun also moving uniformly at the same rate in the plane of the celestial equator.

With the dynamical mean sun and the astronomical mean sun coincident at the first point of Aries and each moving uniformly at the same rate along their respective paths, following the time of the vernal equinox the positions of the two suns are such that the celestial longitude of the dynamical mean sun equals the right ascension of the astronomical mean sun. As shown in the above figure, ♈D = ♈M. As is also shown in this figure, following the vernal equinox the right ascension of the astronomical mean sun is greater than the right ascension of the dynamical mean sun. Thus, during this period that part of the equation of time due to the obliquity of the orbit is a negative value.

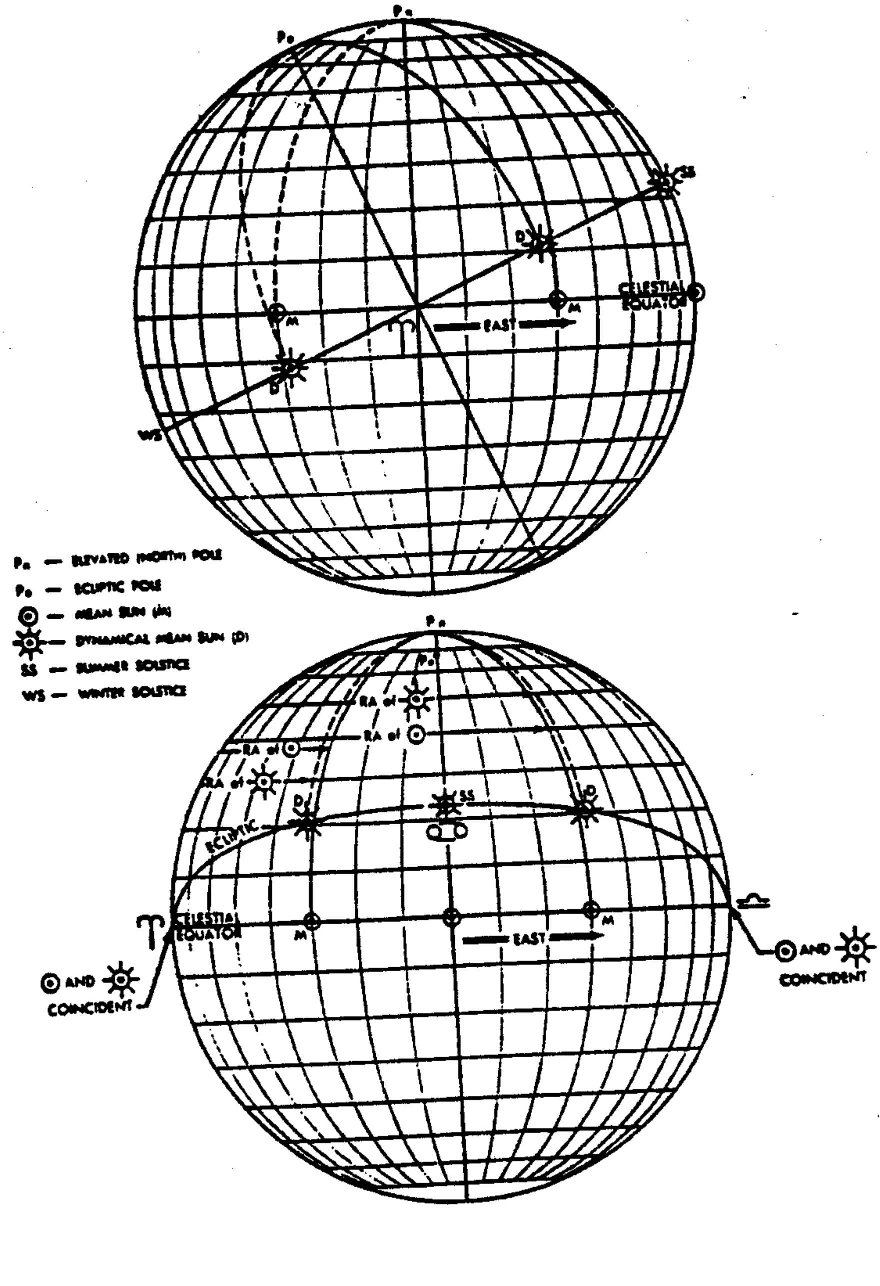
When the celestial longitude of the dynamical mean sun has increased to 90°, the right ascension of the astronomical mean sun will also be 90°. At the time of the summer solstice, the hour circles of the two suns are coincident; the elevated pole, the ecliptic pole, and the two suns all lie on the same great circle. Therefore, at the summer solstice that part of the equation of time due to the obliquity of the orbit is zero. Halfway between the time of the vernal equinox and the summer solstice that part of the equation of time due to obliquity of the orbit reaches a maximum value of about 10 minutes.



Eccentricity component

Following the summer solstice and until the time of the autumnal equinox, the right ascension of the dynamical mean sun is greater than that of the astronomical mean sun. At the autumnal equinox, the two suns are coincident. Following the autumnal equinox and until the time of the winter solstice, the right ascension of the astronomical mean sun is greater than that of the dynamical mean sun. At the winter solstice, the hour angles of the two suns are coincident; the elevated pole, the ecliptic pole, and the two suns all lie on the same great circle. Therefore, at the winter solstice that part of the equation of time due to the obliquity of the orbit is zero. Following the winter solstice and until the time of the vernal equinox, the right ascension of the dynamical mean sun is greater than the right ascension of the astronomical mean sun.

The above figure illustrated that part of the equation of time due to obliquity of the orbit. The above figure illustrates the combining of the two parts. From inspection of the curve it can be seen that the equation of time



Right ascensions of dynamical and astronomical mean suns.

is zero on or about 15 April, 14 June, 1 September, and 24 December. The greater value is about 16^m22^s in November.

Expressing time.—As a measure of part of a day, time based upon the rotation of the earth can be stated in a number of different ways. At any given moment, the time depends upon (1) the point on the celestial sphere used as reference, (2) the reference meridian on the earth, and (3) the somewhat arbitrary starting point of the day.

When the sun is used as the celestial reference point, **solar time** results. If the actual sun observable in the sky is used, **apparent solar time** is involved, and if a fictitious mean sun is used to provide a time having an almost constant rate, mean solar time results. Time reckoned by use of the first point of Aries (♈) as the celestial reference point is called **sidereal time**. Use of the moon as the celestial reference point provides a variable-length lunar day, the basis of **lunar time**, which is useful in tide prediction and analysis. Because of its application, a **lunar day** is sometimes called a **tidal day**. It averages about 24^h50^m (mean solar units) in length.

If the meridian of the observer is used as the terrestrial reference, **local time** is involved. If a **zone** or **standard meridian** in used as the **time meridian** for mean solar time over an area, zone or standard time results. Use of a meridian farther east than would normally be used, so that the period of daylight is shifted later in the day produces a form of zone time called daylight saving or summer time. Time based upon the Greenwich meridian is called Greenwich time. Greenwich mean time (GMT) is of particular interest to a navigator because it is the principal entering argument for the almanacs.

One complete revolution of the earth with respect to a celestial reference point is called a day. In modern usage every kind of solar time has its zero or starting point at midnight, when the celestial reference point is directly over the *lower branch* of the terrestrial reference meridian. This has not always been so. Until January 1, 1925, the astronomical day began at *noon*, 12 hours later than the start of the calendar day of the same date. The nautical day began at noon, 12 hours earlier than the calendar day, or 24 hours earlier than the astronomical day of the same date. This sidereal day begins at sidereal noon, when the

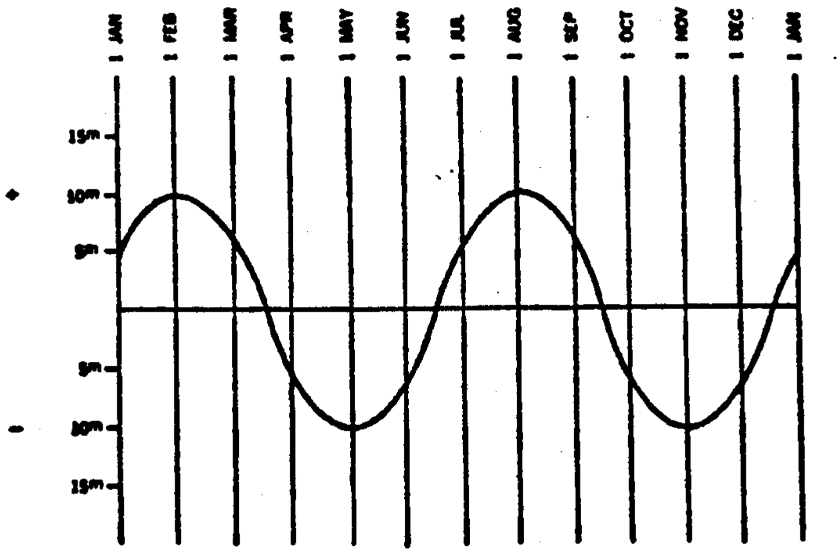
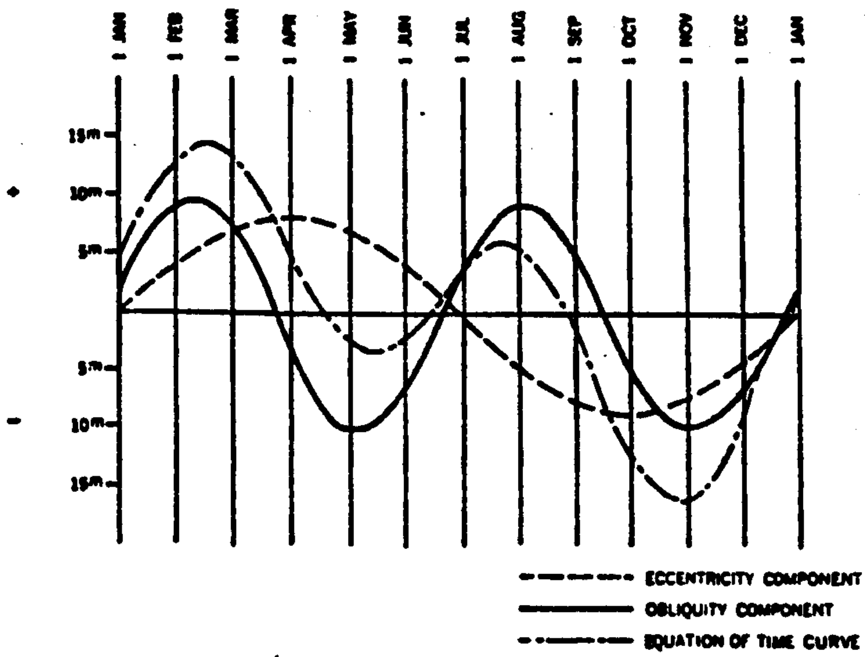


FIGURE 1809d.—Obliquity component.



Equation of time curve constructed from eccentricity and obliquity components.

first point of Aries is over the *upper branch* of the reference meridian. There is no sidereal date.

Time is customarily expressed in time units, from 0^h through 24^h. To the nearest 1^m it is generally stated by navigators in a four-digit unit without punctuation. Thus, 0000 is midnight at the start of the day. One minute later the time is 0001. Half an hour the start of the day the time is 0030, at one hour the time is 0100, at one hour and four minutes it is 0104, at 19 minutes after noon (solar time) it is 1219, at four hours and 23 minutes after (solar) noon it is 1623, etc. The term "hours" is sometimes used with the four-digit system to indicate that the number refers to the time or "hour" of the day. However, in these few occasions when any reasonable doubt may exist as to whether time is indicated, the fact can better be indicated in another way. Thus, the expression "1600 hours" to indicate "1600" or "16 hours" is not strictly correct, and is better avoided. **Watch time (WT),** indicated by a watch or clock having a 12-hour dial, and **chronometer time** (C) are expressed on a 12-hour basis, with designation AM (ante meridian) and PM (post meridian), as in ordinary civil life ashore.

In contrast, a time interval is expressed as hour and minutes, as 5^h26^m. When either the time of day or a time interval is given to seconds, this same form is used, as $21^h15^m18^s$. The kind of time may be indicated, usually by abbreviation.

When a time interval is to be added to or subtracted from a time, the solution can be arranged conveniently in tabular form.

The fact that the sum of hours exceeds 24 is an indication that the date increases by one. Similarly, in subtracting an interval, the date is one day earlier if 24^h must be added to the time before the subtraction can be made. That is, since 2400 of one day is 0000 of the following day, one might say that 2700 on one day is 2700-2400=0300 on the following day. In the example above, $11^h51^m11^s$ on July 25 is the same as $11^h51^m11^s+24^h00^m00^s=35^h51^m11^s$ on July 24.

Date is sometimes expressed as an additional unit of the time sequence. Thus, $21^h14^m18^s$ on July 24 might be stated $24^d21^h14^m18^s$. This system is of particular value when an interval of several days is to be added or subtracted.

By this method thew month and day, if of significance, are recorded separately, or they, too, can be added to the sequence.

Since a month may contain a variable number of days, both the months and days should be solved together. Thus, in the example above, the answer would be 17 months, 39 days. If 12 months are converted to one year, this becomes five months, 39 days. Since the fifth month is May, this might be stated as May 39. Since there are 31 days in May, this is 39-31=8 days into the next month, or June 8.

A simpler method of determining the number of elapsed days between any two dates is to use the **Julian day** of each date, if the information is available. This also eliminated possible error due to change of calendar if long intervals are involved. The Julian day is the consecutive number of the day starting at 1200 on January 1, 4713 BC. Julian day is listed in the Astronomical Almanac.

Time and arc.—The time of day is an indication of the interval since the day began. One day represents one complete rotation of 360° of the earth with respect to a selected celestial point. Each day is divided into 24 hours of 60 minutes, each minute having 60 seconds. Thus, each day has 24×60=1,440 minutes or 1,440×60=86,400 seconds. This is time regardless of the celestial reference point used, and since the various references are in motion with respect to each other, as "seen" from the earth, apparent solar, mean solar, and sidereal days are of different lengths. Since they all have the same number and kind of fractional parts, these parts are themselves of different length in the different kinds of time. Mean solar units are customarily used to indicate time intervals. The smallest unit normally used in celestial navigation is the second, but in some electronic equipment the millisecond (one-thousandth of a second), microsecond (one-millionth of a second), and the millimicrosecond or nanosecond (one-billionth of a second) are used.

Time of day is an indication of the phase of rotation of the earth. That is, it indicates how much of a day has elapsed, or what part of a rotation has been completed. Thus, at zero hours the day begins. One hour later, the earth has turned through 1/24 of a day, or 1/24 of 360°, or

$$\frac{360^\circ}{24} = 15^\circ .$$

Six hours after the day begins, it has turned through 6/24 = ¼ day, or

$$\frac{360^\circ}{4} = 90^\circ .$$

Twelve hours after the start of the day, the day is half gone, having turned through 180°. Similar intervals can also be stated in angular units, for since 1 hour or 60 minutes is equivalent to 15°, 1 minute of time is equivalent to

$$\frac{15^\circ}{60} = 0.25^\circ = 15' .$$

and 1 second of time is equivalent to

$$\frac{15'}{60} = 0'.25 = 15''$$

Thus,

Time	Arc
$1^d = 24^h = 360^\circ = 1$ circle	
$60^m = 1^h = 15^\circ$	
$4^m = 1^\circ = 60'$	
$60^s = 1^m = 15'$	
$4^s = 1' = 60''$	
$1^s = 15'' = 0'.25$	

Any time interval can be expressed as an angle of rotation, and vice versa. Inter-conversion of these units can be made by the relationships indicated above.

To convert time to arc:

1. Multiply the hours by 15 to obtain degrees.
2. Divide the minutes of time by four to obtain degrees, and multiply the remainder by 15 to obtain minutes of arc.

3. **Divide the seconds of time by four to obtain minutes and tenths of minutes of arc, or multiply the remainder by 15 to obtain seconds of arc.**
4. **Add degrees, minutes, and tenths (or seconds).**

To convert arc to time:

1. Divide the degrees by 15 to obtain hours, and multiply the remainder by four to obtain minutes of time.
2. Divide the minutes of arc by 15 to obtain minutes of time, and multiply the remainder by four to obtain seconds of time.
3. Divide the seconds of arc by 15 to obtain seconds of time.
4. Add hours, minutes, and seconds.

The navigator should be able to make these solutions mentally, writing only the answer. As a check, the answer can be converted back to the original value. Solution can also be made4 by means of arc to time tables in the almanacs. In the *Nautical Almanac* the table, given near the back of the volume (app. F), is in two parts, permitting separate entries with degrees, minutes, and quarter minutes of arc. The table is arranged in this manner because the navigator is confronted with the problem of converting arc to time more often than the reverse.

The 22" are converted to the nearest quarter minute of arc for solution to the nearest second of time. Interpolation can be used if more precise results are required, since exact relationships are tabulated in the *Nautical Almanac* conversion table.

In this solution, 58^s4 was obtained by eye interpolation in the quarter-minute part of the table.

A similar table appears near the back of the *Air Almanac* (app. G); however, quarter minutes of arc are not included.

Because the almanac conversion tables are exact relationships, interpolation in them can be carried to any degree of precision desired without introducing an error.

Time and longitude.—As indicated in the preceding article, time is a measure of rotation of the earth, and any given time interval can be represented by a corresponding angle through which the earth turns. Suppose the celestial reference point were directly over a certain

reference of the earth. An hour later the earth would have turned through 15°, and the celestial reference would be directly over a meridian 15° farther west. Any difference of longitude is a measure of the angle through which the earth must rotate for the local time at the western meridian to become what it was at the eastern meridian before the rotation took place. Therefore, places to the eastward of an observer have *later* time, and those to the westward have *earlier* time, and the difference is exactly equal to the difference in longitude, expressed in time units. When a meridian other than the local meridian is used as the time reference, the difference in time of two places is equal to the difference of longitude of their time reference meridians.

The date line.—Since time becomes later toward the east, and earlier toward the west, time at the lower branch of one's meridian is 12 hours earlier or later depending upon the direction of reckoning. A traveler making a trip around the world gains or loses an entire day. To prevent the date from being in error, and to provide a starting place for each day, a **date line** is fixed by international agreement. This line coincides with the 180 th meridian over most of its length. In crossing this line, one alters his date by one day. In effect, this changes his time 24 hours to compensate for the slow change during a trip around the world. Therefore, it is applied in the opposite direction to the change of time. Thus, if a person is traveling *eastward* from east longitude to west longitude, time is becoming *later*, and when the date line is crossed, the date becomes 1 day *earlier*. That is, at any moment the date immediately to the *west* of the date line (east longitude) is 1 day *later* than the date immediately to the *east* of the line, except at GMT 1200, when the (mean time) date is the same all over the world. At any other time two dates occur, one boundary between dates being the date line, and the other being the midnight line along the lower branch of the meridian over which the mean sun is located. At GMT 1200 these two boundaries coincide. In the solution of problems, error can sometimes be avoided by converting local time to Greenwich time, and then converting this to local time on the opposite side of the date line. Examples are given in the following articles.

Zone time.—At sea, as well as ashore, watches and clocks are normally set approximately to some of **zone time (ZT)**. At sea the nearest meridian exactly divisible by 15° is usually used as the time meridian or zone meridian. Thus, within a time zone extending 7°.5 on each side of each time meridian the time is the same , and time in consecutive zones differs by exactly one hour. The time is changed as convenient, usually at a whole hour, near the time of crossing the boundary between zones. Each time zone is identified by the number of times the longitude of its zone meridian is divisible by 15°, positive in west longitude and negative in east longitude. This number and its sign, called the **zone description (ZD)**, is the number of whole hours that are added to or subtracted from the zone time to obtain **Greenwich mean time (GMT)**, which is the zone time at the Greenwich (0°) meridian, and is often called **Universal Time (UT)**. The mean sun is the celestial reference point for zone time.

In converting **GMT** to **ZT**, a positive **ZD** is subtracted, and a negative one added, but its sign remains the same, being part of the description. The word "reversed" (rev.) is written to the right in the work form to indicate that the "reverse" process is to be performed.

When time at one place is converted to that at another, the date should be watched carefully. If a sum exceeds 24 hours, subtract this amount and add one day. If 24 hours are added before a subtraction is made, the date at the place is one day *earlier*.

The second part of this problem might have been solved by using the *difference* in zone description. Since the second place is two zones farther west, its time is two hours earlier. Problems involving zone times at various places generally involve nothing more than addition or subtraction of one small number, so solutions can generally be made mentally. However, when this forms part of a larger problem, or when a record of the solution is desired, the full solution should be recorded, including labels.

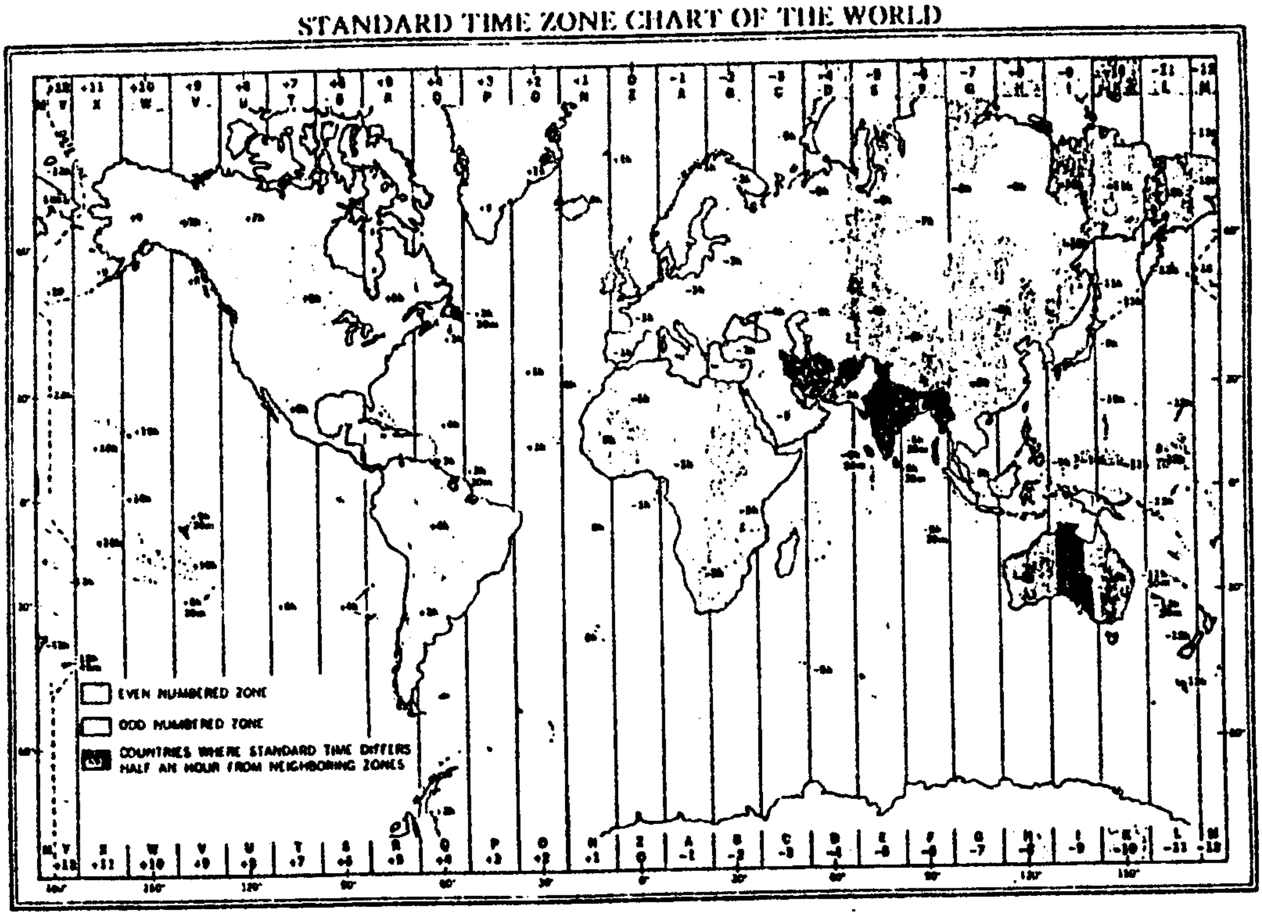
If a time zone boundary had not been crossed, there would have been no need to find **GMT**. It is particularly helpful to retain this step whn the date line is crossed. This line is the center of a time zone, the western (east longitude) half being designed (-) 12, and the eastern (west longitude) half (+) 12.

For certain communication purposes it is sometimes convenient to designate a time zone by a single letter. The system used is shown in the following figure.

Use of time zones on land began in 1883, when railroads adopted four standard zones for the continental United States. The division of the United States into time zones was not officially adopted by Congress, however, until March 19, 1918, when a fifth zone was also established for Alaska. The system of time zones is now used almost universally throughout the world, although on land the zone boundaries are generally altered somewhat for convenience. In a few places, half-hour zones are used but these are not standard time zones.

On land, normal zone time is usually called **standard time**, often with an adjective to indicate the zone, as **eastern standard time.** In some areas timepieces are *advanced* one or more hours during the summer to provide greater use of daylight. This "fast" time is called **daylight saving time** in the United Sates, and **summer time** elsewhere. When time is one hour fast, the zone description is (algebraically) one *less* than normal. When daylight saving or summer time is specified, an advance of one hour is understood unless a greater number is indicated.

STANDARD TIME ZONE CHART OF THE WORLD



Time zone chart of the world.

ZT 0500 Oct. 6

During hostilities daylight saving time may be kept all year long throughout a nation, and designated **war time.**

Chronometer time (C) is time indicated by a chronometer. Since a chronometer is set approximately to GMT, and not reset until it is overhauled and cleaned, perhaps three year later (art. 1514), there is nearly always a **chronometer error** (CE), either *fast* (F) or *slow* (S). The change in chronometer error in 24 hours is called **chronometer rate,** or **daily rate,** and designated gaining or losing. With a Consistent rate of 1^s per day for three years, the chronometer error would be approximately 18^m. Since chronometer error is subject to change, it should be determined from time to time, preferably daily at sea. Chronometer error is found by radio time signal (art. 1826), by comparison with another timepiece of known error, or by applying chronometer rate to previous readings of the same instrument. It is recorded to the nearest whole or half second. Chronometer rate is recorded to the nearest 0^s1.

Because GMT is stated on a 24-hour basis, and chronometer time on a 12-hour basis, a 12-hour ambiguity exists. This is ignored in finding chronometer error. However, if chronometer error is applied to chronometer time to find GMT, a possible 12-hour error can result. This can be resolved by mentally applying zone description to local time to obtain approximate GMT. A time diagram can be used for resolving doubt as to approximate GMT and Greenwich date. If the sun for the kind of time used (mean or apparent) is between the *lower* branches of two time meridians (as the standard meridian for local time, and the Greenwich meridian for GMT), the date at the place farther east is one day *later* than at the place farther *west.*

The A chronometer, usually the best (having the most nearly uniform rate), is compared directly with the time signal (art. 1826). Other chronometers, designated *B*, *C*, etc., may then be compared with the *A* chronometer.

If time signals are not available at the chronometer, a good comparing watch (art. 1516) should be compared with the radio signal, and this watch used to determine chronometer error, as indicated in example 3, substituting the watch for chronometer *A*.

Watch time (WT) is time indicated by a watch. This is usually an approximation of zone time, except that for timing celestial observations it is good practice to set a comparing watch (art. 1516) to **GMT**. If the watch has a second setting hand, the watch can be set exactly to **ZT** or **GMT**, and the time is so designated. If the watch is not set exactly to one of these times, the difference is known as watch error **(WE)**, labeled fast **(F)** or slow **(S)** to indicate whether the watch is ahead of or behind the correct time, respectively.

If a watch is to be set exactly to **ZT** or **GMT**, it is set to some whole minute slightly ahead of the correct time, and stopped. When the set time arrives, the watch is started. It should then be checked for accuracy.

The **GMT** may be in error by 12^h, but if the watch is graduated to 12 hours, this will not be reflected. If a watch with a 24-hour dial is used, the actual **GMT** should be determined.

If watch error is to be determined, it is done by comparing the reading of the watch with that of the chronometer at a selected moment. This may be at some selected GMT.

A more convenient chronometer time might be selected, as a whole minute.

The possible 12^herror is not of significance. When such a watch is used for determining GMT, however, as for entering an almanac, the 12-hour ambiguity is important. Unless a watch is graduated to 24 hours, its time is designated AM before noon and PM after noon.

Note that between 1200 and 1300 watch designations are PM. Between 0000 and 0100 they are AM.

Comparison of a watch and a chronometer should be made carefully. If two observers are available, one can give a warning "stand-by" a few seconds before the selected time, and a "mark" at the appointed moment, while the other notes the time of the watch. A single observer can make a satisfactory comparison by counting with the chronometer. Chronometers beat in half seconds, with an audible "tick". Ten seconds before the selected time (perhaps a whole minute), the observer starts counting with the beats, as he watches the chronometer second hand, "50, and, 1, and, 2, and, 3, and, . . . 9, and, mark. " During the count the observer shifts his view from the chronometer to the second hand of the watch, continuing to

count in cadence with the chronometer beats. At the "mark", the second, minute, and hour hands of the watch are read in that order, and the time recorded. A comparison of this time with the **GMT** or **ZT** corresponding to the selected chronometer time indicates the watch error.

Even though a watch is set to zone time approximately, its error on GMT can be determined and used for timing observations. In this case the 12-hour ambiguity in **GMT** should be resolved, and a time diagram used to avoid possible error. This method requires additional work, and presents a greater probability of error, without compensating advantages.

Still another method of determining **GMT**, generally used before zone time came into common use at sea, is to *subtract* watch time from chronometer time, to find **C-WT**. This is then added to the watch time of an observation to obtain chronometer time **(C – WT+WT=C)**. Chronometer error is then applied to the result to obtain GMT. A time diagram should always by used with this method, to resolve the 12-hour ambiguity and to be sure of the correct Greenwich date, unless an auxiliary solution is made using approximate **ZT** and **ZD**. This method has little to recommend it.

If a watch has a **watch rate** of more than a few seconds per day, watch error should be determined both before and after a round of sights, and any difference distributed proportionally among observations.

If a stopwatch is used for timing observations, it should be started at some convenient **GMT**, as a whole 5^m or 10^m. The time of each observation is then this **GMT** plus the reading of the watch.

Local mean time **(LMT)**, like zone time, uses the mean sun as the celestial reference point. It differs from zone time in that the local meridian is used as the terrestrial reference, rather than a zone meridian. Thus, the local mean time at each meridian differs from that of every other meridian, the difference being equal to the difference of longitude, expressed in time units. At each zone meridian, including 0°, **LMT** and **ZT** are identical.

In navigation the principle use of **LMT** is in rising, setting, and twilight tables. The problem is usually one of converting the **LMT** taken from the table to **ZT**. At sea, the difference between these times is normally not more than 30^m, and the conversion is made directly, without

finding **GMT** as an intermediate step. This is done by applying a correction equal to the difference of longitude (dλ). If the observer is west of his time meridian, the correction is *added*, and if east of it, the correction is *subtracted*. If Greenwich time is desired, it is found from ZT.

On land, with an irregular zone boundary, the longitude may differ by more than $7^\circ.5$ (30^m) from the time meridian.

If **LMT** is to be corrected to daylight saving time, the difference in longitude between the local and time meridian can be used, or the **ZT** can first be found and then increased by one hour.

Conversion of **ZT** (including **GMT**) to **LMT** is the same as conversion in the opposite direction, except that the sign of dλ is reversed. This problem is not normally encountered in navigation.

Apparent time utilizes the **apparent** (real) **sun** as its celestial reference, and a meridian as the terrestrial reference. **Local apparent time (LAT)** uses the local meridian. The LAT at the 0° meridian is called **Greenwich apparent time** (GAT).

The LAT at one meridian differs from that at any other by the difference in longitude of the two places, the place to the eastward having the later time, and conversion is the same as converting **LMT** at one place to **LMT** at another.

Use of the apparent sun as a celestial reference point for time results in time of nonconstant rate for at least three reasons. First, revolution of the earth in its orbit is not constant. Second motion of the apparent sun is along the ecliptic, which is titled with respect to the celestial equator, along which time is measured. Third, rotation of the earth on its axis is not constant. The effect due by this third cause is extremely small.

For the various forms of mean time, the apparent sun is replaced by a fictitious **mean sun** conceived as moving eastward along the *celestial equator* at a uniform speed equal to the average speed of the apparent sun along the ecliptic, thus providing a nearly uniform measure of time equal to the approximate average apparent time. At any moment the accumulated difference between LAT and LMT is indicated by the equation of time (Eq. T), which reaches a maximum value of about $16^m.4$ in November. This quality is tabulated at 12-hour intervals at the bottom

of the right-hand daily page of the *Nautical Almanac*. In the United States, the sign is considered positive (+) if the time of sun's "Mer. Pass". Is earlier than 1200, and negative (-) if later than 1200. If the "Mer. Pass." Is given as 1200 (as on June 12-14, 1975), the sign is positive if the GHA at GMT 1200 is between 0° and 1°, and negative if it is greater than 359°. The sign is correct for conversion of GMT to GAT. In Great British, this convention is reversed. Since GMT is the entering argument for the almanacs, interconversion of apparent and mean time should preferably be made from Greenwich time, rather than from local time.

In conversion from apparent to mean time, a second solution may be needed if the equation of time is large and changing rapidly, using the GAT for entering the almanac for the first solution and using the GMT from this solution as the almanac entry value for the second solution.

Apparent time can also be found by converting hour angle to time units, and adding or subtracting 12 hours. If LAT is required, but not GAT, conversion of arc to time should be made from LHA, rather than GHA, to avoid the need for conversion of longitude to time units. Equation of time can be found by subtracting mean time from apparent time at the same meridian. This method of finding apparent time and equation of time is the only one available with the *Air Almanac*, which does not tabulate equation of time.

The navigator has little or no use for apparent time, as such. However, it can be used for finding the time of local apparent noon (LAN), when the apparent sun is on the celestial meridian.

The mean sun average out the irregularities in time due to the variations of the speed of revolution of the earth in its orbit and the fact that the apparent sun moves in the ecliptic while hour angle is measured along the celestial equator. It does not eliminate the error due to slight variations in the *rotational* speed of the earth. When a correction for the accumulated error from this source is applied to mean time, Ephemeris Time results. This time is of interest to astronomers, but is not used directly by the navigator.

Sidereal time uses the first point of Aries (vernal equinox) as the celestial reference point. Since the earth revolves around the sun, and since the direction of the earth's rotation and revolution are the same, it

completes a rotation with respect to the stars in less time (about $3^m56^s.6$ of mean solar units) than with respect to the sun, and during one revolution about the sun (1 year) it makes one complete rotation more with respect to the stars than with the sun. This accounts for the daily shift of the stars nearly 1° westward each night. Hence, sidereal days are shorter than solar days, and its hours, minutes, and seconds are correspondingly shorter. Because of nutation (art. 1417) sidereal time is not quite constant in rate. Time based upon the average rate is called mean sidereal time, when it is to be distinguished from the slightly irregular sidereal time. The ratio of mean solar time units to mean sidereal time units is 1:1.00273791.

The sidereal day begins when the first point of Aries is over the upper branch of the meridian, and extends through 24 hours of sidereal time. The sun is at the first point of Aries at the time of the vernal equinox, about March 21. However, since the solar day begins when the sun is over the lower branch of the meridian, apparent solar and sidereal times differ by 12 hours at the vernal equinox. Each month thereafter, sidereal time gains about 2 hours time. By the time of the summer solstice, about June 21, sidereal time is 18 hours ahead or 6 hours behind solar time. By the time of the autumnal equinox, about September 23, the two times are together, and by the time of the winter solstice, about December 22, the sidereal time is 6 hours ahead of solar time. Therefore need be no confusion of the date, for there is no sidereal date.

Local sidereal time (LST) uses the local meridian as the terrestrial reference. At the prime meridian this is called **Greenwich sidereal time (GST)**. The difference between **LST** at two meridians is equal to the difference of longitude between them, the place to the eastward having the later time. Local sidereal time is **LHAϒ** expressed in time untis. To determine **LST** at any given moment, find **GHAϒ** by means of an almanac, and then apply the longitude to convert it to **LHAϒ**. Then convert **LHAϒ** in arc to **LST** in time units.

Unless GST is required, conversion from arc to time units should be made from LHAϒ, rather than from **GHAϒ**, to avoid the need for converting longitude from arc to time units.

Conversion of sidereal to solar time is the reverse. Local sidereal time is converted to arc (LHAϒ), and the longitude is applied to find GHAϒ. This is used as an argument for entering the almanac to determine GMT, which can then be converted to any other kind of time desired. This is similar to one method of finding time of meridian transit, described in article 2104. Normally, the problem is not encountered by the navigator.

Sidereal time, as such, is little used by the navigator. It is the basis of star charts (art. 2204) and star finders (art. 2210), and certain sight reduction methods (notably Pub. No. 249), but generally in the form LHAϒ. This kind of time is used for these purposes because its celestial reference point remains almost fixed in relation to the stars. Sidereal time is used by astronomers to regulate mean time. Timepieces regulated to sidereal time can be purchased.

Time and hour angle. –Both time and hour angle are a measure of the phase of rotation of the earth, since both indicate the angular distance of a celestial reference point west of a terrestrial reference meridian. Hour angle, however, applies to any point on the celestial sphere. Time might be used in this respect, but only the apparent sun, mean sun, the first point of Aries, and occasionally the moon are commonly used.

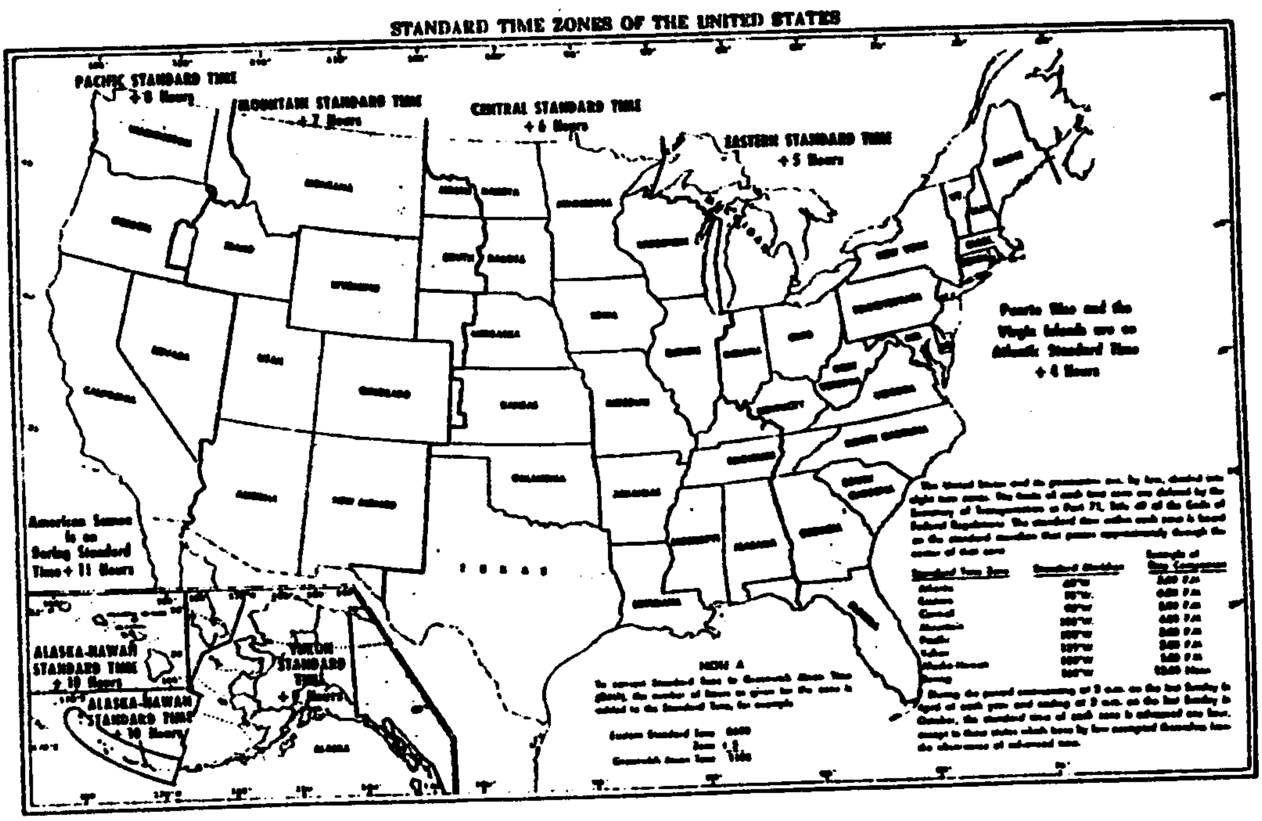
Hour angles are usually expressed in arc units, and are measured from the upper branch of the celestial meridian. Time is customarily expressed in time units. Sidereal time is measured from the upper branch of the celestial meridian, like hour angle, but solar time is measured from the lower branch. Thus, **LMT = LHA** mean sun plus or minus 180°, **LAT =** **LHA** apparent sun plus or minus 180°, and **LST = LHAϒ**.

As with time, **local hour angle (LHA)**, based upon the local celestial meridian, at two places differs by the longitude between them, and LHA at longitude 0° is called **Greenwich hour angle (GHA)**. In addition, it is often convenient to express hour angle in terms of the *shorter* arc between the local celestial meridian and the body. This is similar to measurement of longitude from the Greenwich meridian. Local hour angle measured in this way is called **meridian angle (t)**, which is labeled *east* or *west*, like longitude, to indicate the direction of measurement. A westerly meridian angle is numerically equal to LHA, while an easterly meridian angle is equal to 360°–LHA; also, LHA = t (W), and LHA =360° -t (E).

Meridian angle is used in the solution of the navigational triangle (art. 1433).

The legal basis of standard time in the United States is contained in the "Uniform Time Act of 1966" (Public Law 89-387) and the U.S. Code, Title 15. This act reiterates the policy of the United States to "promote the adoption and observance of uniform time within prescribed Standard Time Zones. . ." and establishes the annual advancement and retardation of standard time by 1 hour the last Sunday of April and October, respectively. The Department of Transportation is the agency designated for enforcement of the law.

The "Uniform Time Act" establishes eight Standard Time Zones for the United States (the following figure) and notes that standard time is based on the mean solar time of specified longitudes. The reference meridians are spaced 15° apart in longitude beginning with the meridian through Greenwich, England. Time zones extend 7½° in longitude on each side with considerable variation in boundaries to conform to political or geographic boundaries or both. Since the time zones are 15° apart, the time difference between two adjacent zones is 1 hour.



Standard Time zones of the United States of America

A comprehensive delineation of these zones is given in the **code of Federal Regulations**, entitled "Standard Time Zone Boundaries".

This system of time zones is now used almost universally throughout the world, although on land the zone boundaries are generally altered somewhat for convenience. In a few places, half-hour zones are used.

The standard times used in various countries and places are tabulated in the almanacs.

Radio Dissemination of Time Signals

Dissemination system. –Of the many systems for time and frequency dissemination, the majority employ some type of radio transmission, either in dedicated time and frequency emissions or established systems such as radio navigation systems and television. The most accurate means of time and frequency dissemination today is through on site visits or aircraft flyovers with portable atomic clocks.

Radio time signals can be used either to perform a clock function or to set clocks. When one uses a radio wave instead of a clock, however, new considerations evolve. One is delay time of approximately 3 microseconds per kilometer it takes the radio wave to propagate and arrive at the reception point. Thus, a user 1,000 kilometers from a transmitter receives the time signal about 3 milliseconds later than the on-time transmitter signal. If time is needed to better than 3 milliseconds, correction must be made for the signal to pass through the receiver.

In most cases standard time and frequency emissions as received are more than adequate for ordinary needs. However, many systems exist for the more exacting scientific requirements.

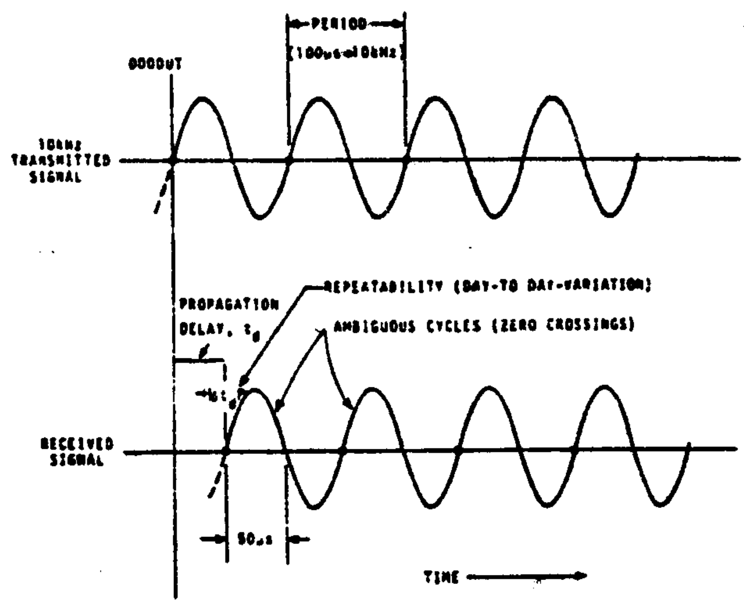
Astronomers, geodesists, navigators, and others using time based on the earth's rotation (UT1) require that the emissions of Coordinated Universal Time (UTC) also include the difference between UTC and UT1. This difference is discussed in art.1827.

Characteristic elements of dissemination system. –A number of common elements characterize most time and frequency dissemination systems. Among the more important elements are accuracy, ambiguity, repeatability, coverage, availability of time signal, reliability, ease of use, cost to the user, and the number of users served. There does not now

appear to be any single system which incorporates all desired characteristics. The relative importance of these characteristics will vary from one user to the next, and the kind of compromise solution for one user may not be satisfactory to another. These common elements are discussed in the following examination of a possible radio signal.

Consider a very simple system consisting of an unmodulated 10-kHz signal as shown in the following figure. A positive going zero-crossing of this signal, leaving the transmitter at 0000 UTC, will reach the receiver at a later time equivalent to the propagation delay. The user must know this delay because the accuracy of his knowledge of time can be no better than the degree to which this delay is known. (By accuracy is meat the degree of conformity to some specified value or definition.) Since all cycles of the signal are identical, the signal is ambiguous and the user must somehow decide which cycle is the "on time" cycle. This means, in the case of the hypothetical 10-kHz signal, that the user must know the time to ± 50 microseconds (half the period of the signal). Further, the user may desire to use this system, say once a day, for an extended period of time to check his clock or frequency standard. However, it may be that the delay will vary from one day to the next, and if the user is unaware of this variation, his accuracy will be limited by the lack of repeatability of the signal arrival time.

Many users are interested in making time coordinated measurements over large geographic areas. They would like all measurements to be referenced to one time system to eliminate corrections for difference time systems used at scattered or remote location. This is a very important practical consideration when measurements are undertaken in the field. In addition, a one reference system, such as a single time broadcast, increases confidence that all measurements can be related to each other in some known way. Thus, the *coverage* of a system is an important concept. Another important characteristic of a timing system is the *percent of time available*. The man on the street who has to keep an appointment needs to know the time perhaps to a minute or so. Although



Single tone time dissemination.

he required only coarse time information, he wants it on demand so he carries a wristwatch that gives the time to him 24 hours a day. On the other hand, a user who needs time to a few microseconds employs a very good clock which only needs an occasional update, perhaps only once or twice a day. An additional characteristic of time and frequency dissemination is *reliability*, i.e., the likelihood that a time signal will be available when scheduled. Propagation fadeout can sometimes prevent reception of HF signals.

Radio propagation factors. –Radio has offered good means of transferring standard time and frequency signals since the early 1900's. As opposed to the physical transfer of time via portable clocks, the transfer of information by radio entails propagation of electromagnetic energy through some propagation medium from a transmitter to a distant receiver.

In a typical standard frequency and time broadcast, the signals are directly related to some master clock and are transmitted with little or no

degradation in accuracy. In a vacuum and noise free background, the signals should be received at a distant point essentially as transmitted, except for a constant path delay with the radio wave propagation near the speed of light (i.e., 299,773 kilometers per second). The propagation media, including the earth, atmosphere, and ionosphere, as well as physical and electrical characteristics of transmitters and receivers, influence the stability and accuracy of received radio signals, dependent upon the frequency of the transmission and length of signal path. Propagation delays are affected in varying degrees by extraneous radiation's in the propagation media, solar disturbances, diurnal effects, and weather conditions, among others.

Radio dissemination systems can be classified in a number of different ways. One way is to divide those carrier frequencies low enough to be reflected by the ionosphere (below 30 MHz) from those sufficiently high to penetrate the ionosphere (above 30 MHz). The former can be observed at great distances from the transmitter but suffer from ionosphere propagation anomalies that limit accuracy; the latter are restricted to line-of-sight applications but show little or no signal deterioration caused by propagation anomalies. The most accurate systems tend to be those which use the higher, line-of-sight frequencies, while broadcasts of the lower carrier frequencies show the greatest number of users.

Standard time broadcasts.—The World Administrative Radio Council (WARC) has allocated certain frequencies in five bands for standard frequency and time signal emission as shown in table 1825. For such dedicated standard frequency transmissions, the International Radio Consultative Committee (CCIR) recommends that carrier frequencies be maintained so that average daily fractional frequency deviations from the internationally designated standard for measurement of time interval should not exceed 1×10^{-10}. The U.S. Naval Observatory *Time Service Announcement Series 1, No.2*, gives characteristics of standard time signals that are assigned to allocated bands, as reported by the CCIR.

Time signals.—The usual method of determining chronometer error and daily rate is by radio time signals, popularly called **time ticks.** Most maritime nations broadcast time signals several times daily from one or

more stations, and a vessel equipped with radio receiving equipment normally has no difficulty in obtaining a time tick anywhere in the world. Normally, the time transmitted is maintained virtually uniform with respect to atomic clocks. The Coordinated Universal Time (UTC) as received by a vessel may differ from UT1 (GMT) by as much as $0^s.9$ (art. 1828).

The majority of radio time signals are transmitted automatically, being controlled by the standard clock of an astronomical observatory. Absolute reliance may be hand in these signals, and they should be correct to 0.05 second. Some stations transmit by a combination of hand and automatic signals, and care should be exercised to different between two at the time of actual comparison of the chronometer.

Other radio stations, however, have no automatic transmission system installed, and the signals are given by hand. In this instance the operator is guided by the standard clock at the station. The clock is checked by their astronomical observations or by reliable time signals. The hand transmission should be correct to 0.25 second.

Band No.	Designation	Frequency Range
4	VLF (Very Low Frequency).	20.0 kHz±50 Hz.
6	MF (Medium Frequency).	2.5 MHz±5 kHz.
7	HF (High Frequency)	5.0 MHz±5 kHz. 10.0 MHz±5 kHz. 15.0 MHz±10 kHz. 20.0 MHz±10 kHz. 25.0 MHz±10 kHz.
9	UHF (Ultra High Frequency).	400.1 MHz±25 kHz (satellite).
10	SHF (Super High Frequency).	4.202 GHz±2 MHz (satellite-space to earth). 6.427 GHz±2 MHz (satellite-earth to space).

International Standard Time and frequency radio assignments.

At sea the spring-driven chronometer should be checked daily by radio time signal, and in port daily checks should be maintained, or begun at least three days prior to departure, if conditions permit. Error and rate are entered in the chronometer record book (or record sheet) each time they are determined.

The various time signal systems used throughout the world are discussed in Pubs. Nos. 117A and 117B, *Radio Navigational Aids*, and volume 5 of *Admiralty List of Radio Signals*. Only the United States signals discussed here.

The U.S. Naval Observatory at Washington D.C., controls the transmissions of time signals from U. S. Naval radio stations. Beginning at 5 minutes before each even hour of GMT, dashes are transmitted on every second, except the 29th and certain others near the end of each minute, as shown in the following diagram:

Minutes	Seconds										
	50	51	52	53	54	55	56	57	58	59	60
55	--		--	--	--	--					--
56	--	--		--	--	--					--
57	--	--	--		--	--					--
58	--	--	--	--		--					--
59	--										--

The seconds marked "60" indicate the start of the next minute. The final dash, marking the hour, is considerably longer than any of the others. The number of dashes in the group near the end of any minute indicates the number of minutes before the hour. This is known as the United States system. In all cases the beginnings of the dashes indicate the beginning of the seconds, and the ends of the dashes are without significance.

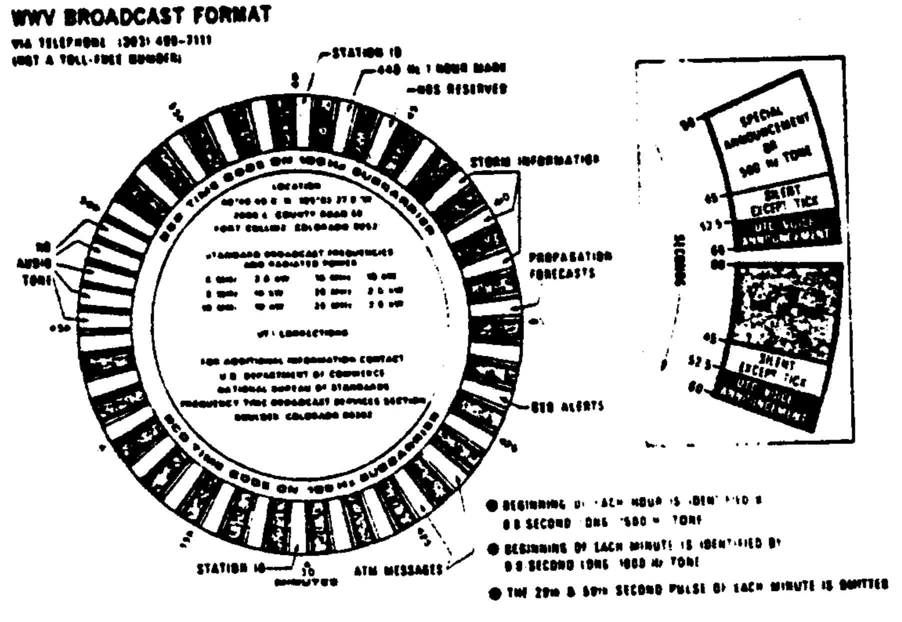
Although the broadcasts of the Nautical Bureau of Standards (NSB) stations WWV and WWVH are intended primarily for dissemination of frequency and time *interval* for scientific purposes, time ticks are also provided.

Station WWV broadcast from Fort Collins, Colorado at the international allocated frequencies of 2.5, 5.0, 10.0, 15.0, 20.0, and 25.0 MHz; station WWVH transmits from Kauai, Hawaii on the same frequencies with the exclusion of 25.0 MHz. The hourly broadcast formats are shown in the following figure. The broadcast signals include standard time and frequencies and various voice announcements. Details of these broadcast are given in NBS Special Publication 236, NBS Frequency and Time broadcast Services. Both HF emissions are directly controlled by cesium beam frequency standard with periodic reference to the NBS atomic frequency and time standard; corrections are published monthly.

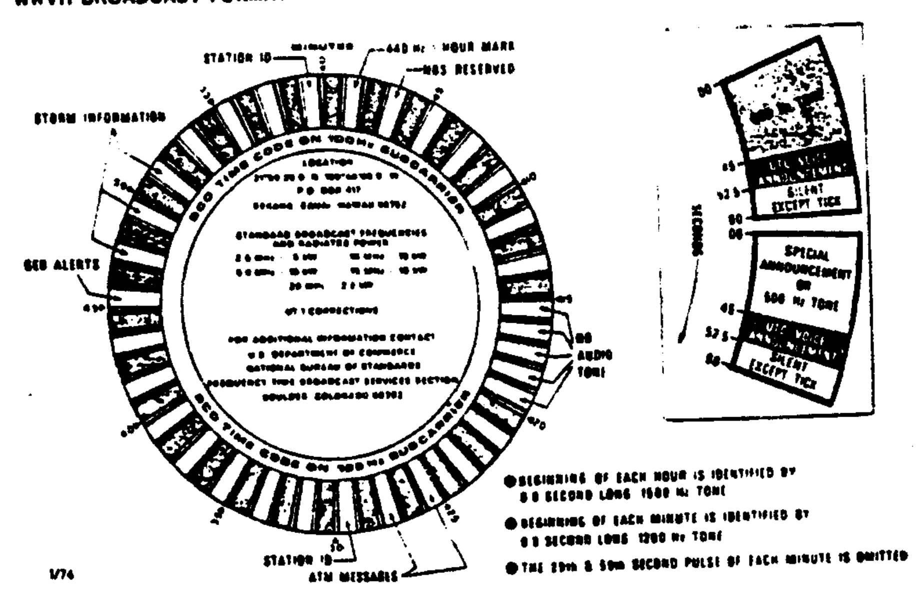
The time ticks in the WWV and WWVH emissions are shown in the following figure. The 1-second UTC markers are transmitted continuously by WWV and WWVH, except for emission of the 29th and 59th marker each minute. With the exception of the beginning tone at each minute (800 milliseconds) all 1-second markers are of 5 milliseconds duration. Each pulse is preceded by 10 milliseconds of silence and followed by 25 milliseconds of silence. Time voice announcements are given also at 1-minute intervals. All time announcements are UTC.

Codes for the transmission of DUT1.—The difference between UTC and UT1 is known as DUT1, the relationship being DUT1 = UT1 − UTC. By means of a coding system incorporated in the actual emissions, primary time signal sources promulgate DUT1 in integral multiples of 100 milliseconds.

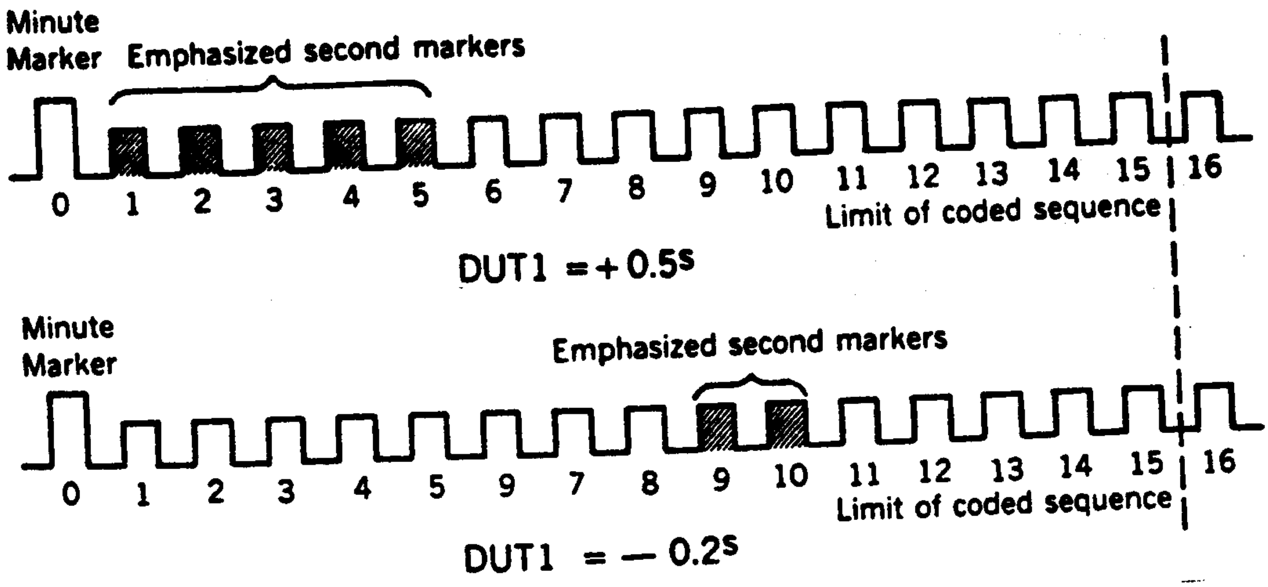
WWV BROADCAST FORMAT



WWVH BROADCAST FORMAT



Broadcast format of stations WWV and WWVH



CCIR code for transmission of DUT1.

The CCIR standard format is in the form of emphasized second markers utilizing the first 15 seconds following the minute marker. The emphasis of the second markers can take the form of lengthening, doubling, splitting, or tone modulation of the normal seconds markers. Each emphasized second represents a DUT1 value of $0^s.1$.

A positive value of DUT1 is indicated by emphasizing a number (n) of consecutive seconds markers following the minute marker from seconds markers one to seconds marker (n) inclusive; (n) is an integer from 1 to 8 inclusive (the above figure).

$$DUT1 = (n \times 0.1)s.$$

A negative value of DUT1 is indicated by emphasizing a number (m) of consecutive seconds markers following the minute marker from seconds marker nine to seconds marker (8 + m) inclusive; (m) is an integer from 1 to 8 inclusive.

$$DUT1 = -(m \times 0.1)s.$$

A zero value of DUT1 is indicated by the absence of emphasized seconds markers.

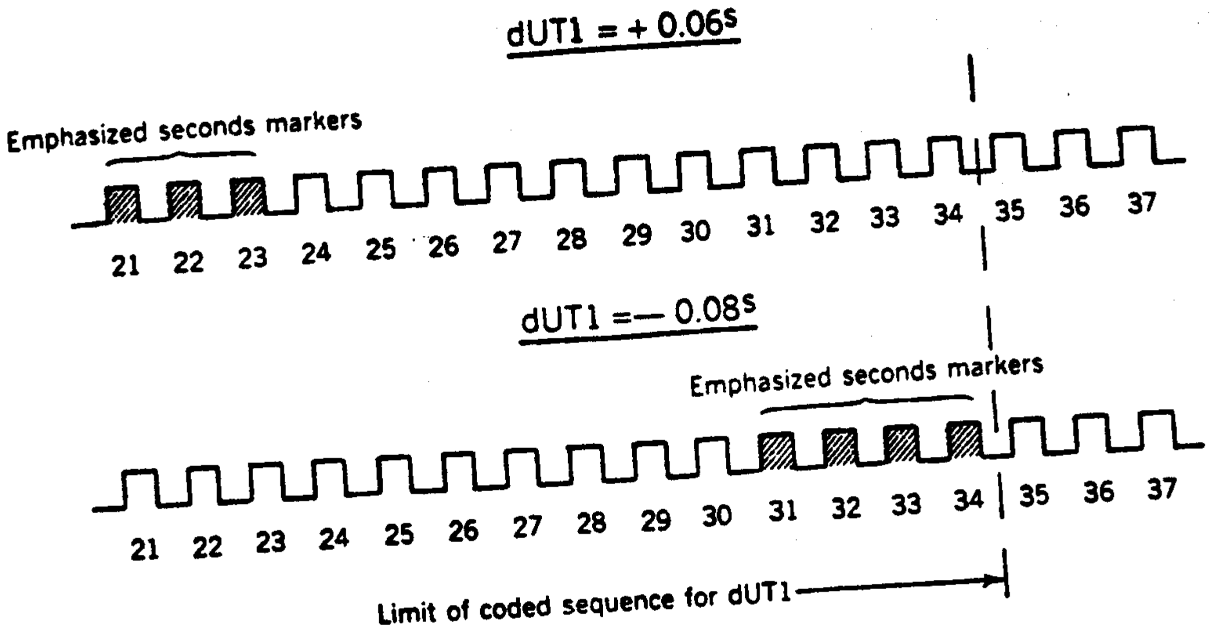
The National Bureau of Standards stations WWV and WWVH transmit DUT1 using the CCIR standard format. The CCIR standard format is used by most coordinated stations, including CHU, Canada.

In the USSR extended format, the CCIR format is followed for DUT1. In addition dUT1 is given to specify more precisely the difference UT1-UTC to multiple of $0^s.02$, the total value of the correction being DUT1 + dUT1. Positive values of dUT1 are transmitted by the marking of p second markers between the 21st and 24th second (the following figure) so that dUT1 = (p × 0.02)s. Negative values of dUT1 are transmitted by the marking of a q second markers between the 31st and 34th second, so that dUT1 = - (q × 0.02)s.

DUT1 may also be given by voice announcement or in Morse code. In the **More code method,** U.S. Naval Radio Stations use standard Morse code (15 words per minute) between seconds 56 and 59 inclusive of each minute not used for time ticks to indicate the sign and value in tenths of a second of DUT1. Positive values are indicated by the letter "A" and the appropriate digit; negative values are indicated by the letter "S" and the appropriate digit.

Standard Morse

A	S...
1	6
2	7
3	8
4	9
5	0



USSR extended format for transmission of dUT1.

For example :

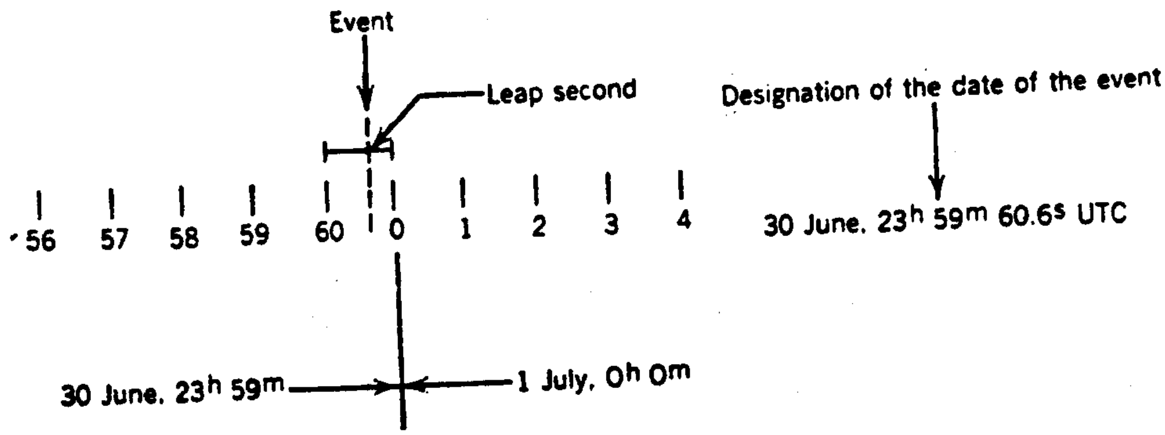
" . . . . " means DUT1 = -0^s.1 and UT1 = UTC – 0^s.1.

Pubs. Nos. 117A and 117B, *Radio Navigational Aids*, should be referred to for up-to-date information on time signals.

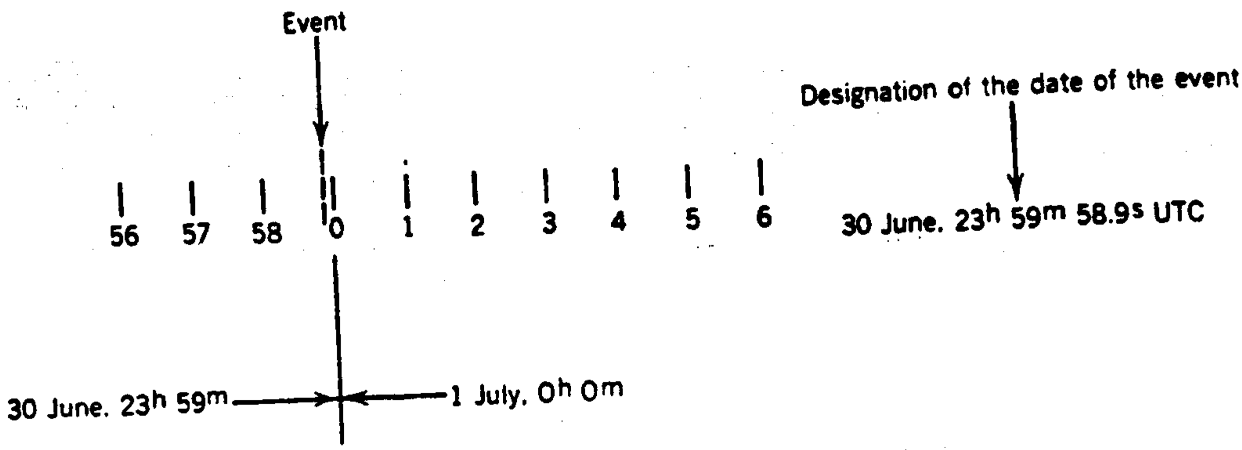
Leap-second adjustments. –By international agreement, UTC is maintained within about 0^s.9 of the celestial navigator's time scale, UT1. The introduction of leap seconds allows a good clock to keep approximate step with the sun. Because of the variations in the rate of rotation of the earth, however, the occurrences of the leap seconds are not predictable in detail.

The Bureau International de l'Heure (BIH) decides upon and announces the introduction of a leap second. The BIH announces the new leap second at least several weeks in advance. A positive or negative leap second is introduced the last second of a UTC month, but first preference is given to the end of December and June, and second preference is given

to the end of March and September. A positive leap second begins at $23^h59^m60^s$ and ends at $00^h00^m00^s$ of the first day of the following month. In the case of a negative leap second, $23^h59^m58^s$ is followed one second later by $00^h00^m00^s$ of the first day of the following month.



Dating of event in the vicinity of a positive leap second.



Dating of event in the vicinity of a negative leap second.

The dating of events in the vicinity of a leap second is effected in the manner indicated in the above figures.

Whenever leap second adjustment are to be made to UTC, mariners are advised by HYDROLANT/HYDROPAC messages originated by the Defense Mapping Agency Hydrographic/Topographic Center.

Problems

What is the time and date $9^h13^m29^s$ before $3^h16^m34^s$ May 9?

Answer. –T $18^h03^m05^s$ May 8.

What is the time and date $4^d19^h22^m50^s$ after $9^h31^m04^s$ on December 25?

Answer. –T $4^h53^m54^s$ on Dec. 30.

What is the time and date 2 years, 11 month, 16 days, 10 hours, 23 minutes, and 48 seconds before $2^h46^m17^s$ on October 4, 1958?

Answer. –T $16^h22^m29^s$ on Oct. 17, 1995.

What is the time and date 412 days, 15 hours, 6 minutes, and 56 seconds after $22^h27^m03^s$ on March 16, 1958?

Answer. –T $13^h33^m59^s$ on May 3, 1959.

Convert $6^h28^m31^s$ to arc units, without use of a conversion table.

Answer. –97° 07′45″ or 97°07′.8.

Convert 217°28′.8 to time units, without use of a conversion table.

Answer. $-14^h29^m55^s.2$ or $14^h29^m55^s$.

Convert 196°21′46″ to time units, without use of a conversion table.

Answer. $-13^h05^m27^s.1$ or $13^h05^m27^s$.

Convert 107°49′44″ to time units, using appendix F.

Answer. $-7^h11^m19^s$.

Convert 211°37′.3 to time units, using appendix F.

Answer. $-14^h06^m29^s.2$.

Convert $8^h49^m33^s$ to arc units, using appendix F.

Answer. $-132°23^s.2$.

Convert 251°09′.2 to time units, using appendix G.

Answer. $-16^h44^m37^s$.

Convert $23^h07^m38^s$ to arc units, using appendix G.

Answer. –346°54′.5.

For an observer at long. 97°24′.6E the ZT is $19^h10^m26^s$.

Required. –(1) Zone description.

(2) **GMT.**

Answers. –(1) ZD (-) 6, (2) GMT $13^h10^m26^s$.

The GMT is $11^h32^m07^s$.

Required.-(1) ZT at long. 133°24'.7W.

(2) ZT at long. 111°43'.9E.

Answer. –(1) ZT $2^h32^m07^s$, (2) ZT $18^h32^m07^s$.

At long. 165°18'.2E the ZT is $17^h08^m51^s$ on July 11.

Required. –(1) GMT and date.

(2) ZT and sate at long. 125°36'.7W.

Answer.—(1) GMT $6^h08^m51^s$on July 11, (2) ZT $22^h08^m51^s$ on July 10.

On January 26 the 0800 DR long. of a ship is 128°03'.2E. Twenty-six hours later the EO long. is 125°01'.4E.

Required. –ZT and date of arrival at the second longitude.

Answer. –ZT 0900 Jan. 27.

On April 1 the 1200 running fix long. of a ship is 179°55'.2W. Eight hours later the DR long. is 178°48'.9E.

Required. –ZT and date of arrival at the second longitude.

Answer. –ZT 2000 Apr. 2.

Inch on, long. 137°E, uses ZD (-) 8^h30^m for standard time. Find the standard time and date at San Francisco, long. 122°W, when the summer time at Inch on is 2000 on August 9.

Answer. –ZT 0230 Aug. 9.

At GMT 1400 on July 2 the chronometer reads $1^h42^m28^s$. At GMT 0800 on July 12 it reads $7^h42^m40^s$.

Required. –(1) Chronometer error at GMT 1400 on July 2.

(2) Chronometer error at GMT 0800 on July 12.

(3) Chronometer rate.

(4) Chronometer time at ZT 1800 July 20, at long. 153°21'.7W.

Answer.—(1) CE 17^m32^s slow, (2) CE 17^m20^s slow, (3) rate $1^s.2$ gaining, (4) C$3^h42^m51^s$.

On March 5 the DR long. of a ship is about 151° E, and the zone time is about 1800. Chronometer error is 6^m40^s fast.

Required. –GMT and date when the chronometer reads $8^h02^m23^s$.

Answer. –GMT $7^h55^m43^s$ on Mar. 5.

On November 7 the EP long. of a ship is about 71° W, and the zone time is about 1900. Chronometer error is 1^m18^s slow.
Require.—GMT and date when the chronometer reads (1) $11^h55^m20^s$, (2) $11^h59^m50^s$.
Answer. –(1) GMT $23^h56^m38^s$ Nov. 7, (2) GMT $0^h01^m08^s$ Nov. 8.
At GMT 2200 a comparing watch is checked by time signal, and found to read $10^h00^m05^s$. The chronometer errors are then determined by means of the comparing watch. When the watch reads $10^h06^m00^s$, chronometer A reads $10^h11^m17^s$, and when the watch reads $10^h08^m00^s$, chronometer B reads $9^h59^m06^s$.
Required. –(1) Watch error.
(2) Error of chronometer A.
(3) Error of chronometer B.
Answers. –(1) WE 5^s fast on GMT, (2) CE_A 5^m22^s fast, (3) CE_B 8^m49^s slow.
A chronometer 7^m22^s slow on GMT reads approximately 3^h45^m. About 2 minutes later, when the GMT is a whole minute, a comparing watch will be set to GMT exactly.
Required. –(1) Reading of the watch at starting.
(2) Reading of the chronometer.
Answers. --(1) WT $3^h54^m00^s$, (2) $3^h46^m38^s$.
A chronometer 5^m10^s fast on GMT reads approximately 5^h50^m. About 1 minute later, when the GMT is a whole minute, a comparing watch with a 24-hour dial will be set to GMT exactly. The ZT is approximately 1145 and the long. 94°W.
Required.—(1) Reading of the watch at starting.
(2) Reading of the chronometer.
(3) Watch error if, instead of being set to GMT, the watch setting is unchanged and the watch reads $17^h45^m32^s$ at comparison.
Answers.—(1) WT $17^h46^m00^s$, (2) C $5^h51^m10^s$, (3) WE 28^s slow on GMT.
A watch is set to zone time, approximately. The long. is about 160° E. The watch is compared with a chronometer which is 3^m16^s fast on GMT. When the chronometer reads $1^h48^m00^s$, the watch reads $12^h45^m02^s$.
Required. –Watch error on zone time.
Answer. –WE 18^s fast on ZT.

On February 14 the DR long. is 63°46'1W. An observation of Dubhe is made when the watch reads $6^h07^m30^s$ PM. The watch is 11^s slow on zone time.

Required. –GMT and date.

Answer. –GMT $2207^m41^{sh}07^m41^s$Feb. 14.

On December 11 a watch is et to zone time, approximately. The long. is 137°W. The chronometer is 3^m36^s fast on GMT. When the chronometer reads $4^h40^m00^s$, the watch reads $7^h36^m06^s$ PM.

Required. –(1) Convert WT to GMT and determine watch error.

GMT and date about 20 minutes later, when the uncorrected watch reads $7^h55^m52^s$.

Answers. –(1) WE 18^sslow, (2) GMT $4^h56^m10^s$ Dec. 12.

Shortly before morning sights on January 17 the navigator compares his watch with the chronometer. When the chronometer reads $2^h30^m00^s$, the watch reads $6^h13^m12^s$AM. The chronometer is 17^h15^s fast on GMT. The long. is 118°W.

Required. –(1) C –WT.

GMT and date a little later when Regulus is observed at W $6^h28^m47^s$AM.

Answers. –(1) C – WT $8^h16^M48^s$, (2) GMT $14^h28^m20^s$ Jan. 17.

At long. 138°09'.3E the LMT is $0^h09^m57^s$ on April 23.

Required. –(1) GMT and date.

(2) ZT and date at the place.

Answers.—(1) GMT $14^h57^m20^s$ Apr. (2) ZT $23^h57^m20^s$ Apr. 22.

At long. 157°18'.4W the LMT is 1931 on June 29.

Required. –(1) ZT and date.

(2) GMT and date.

Answers. –(1) ZT 2000 June 29, (2) GMT 0600 June 30.

At long. 99°35'.7W the daylight saving time is $21^h29^m45^s$ on August 31.

Required.—(1) Standard time and date.

(2) LMT and date.

Answers. –(1) Standard time $20^h29^m45^s$ Aug. 31, (2) LMT $20^h51^m22^s$ Aug. 31.

Find the LAT and date at ZT $5^h26^m13^s$ on June 12, 1975, for long. 9°28'1E.

Answer. –LAT $5^h04^m21^s$ June 12.

At long. 77°15'.5W the LAT is 1500 on June 13, 1975.
Required. –(ZT).
(2) LMT.
Answers. –(1) ZT $15^h08^m56^s$, (2) LMT 14^h5954^s.
Using the Air Almanac, find (1) LAT at long. 117°55'W, and (2) the Eq. T, at ZT $20^h43^m09^s$ on June 1, 1975.
Answers. –(1) LAT $20^h53^m44^s$, (2) Eq. T (+) 2^m15^s.
Fins LST at ZT $19^h24^m26^s$ on June 1, 1975, for long. 87°51'.2E.
Answer. -LST $11^h53^m29^s$.
Find the ZT at LST $21^h20^m07^s$ on May 31, 1975, for long. 54°21'.3W.
Answer. –ZT $4^h24^m40^s$.

CHAPTER II

CHART PROJECTIONS

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CHART PROJECTIONS
General

The navigator's chart. – A map is a conventional representation, usually on a plane surface, of all or part, of the physical features of the earth's surface or any part of it. A chart is such a representation intended primarily for navigation. A nautical or marine chart is one intended primarily for marine navigation. It generally shows depths of water (by sounding and sometimes also by depth curves), aids to navigation, dangers, and the outline of adjacent land and such land features as are useful to the navigator.

Chart making presents the problem of representing the surface of a spheroid upon a plane surface. The surface of a sphere or spheroid is said to be undevelopable because no part of it can be flattened without distortion. A map projection or chart projection is a method of representing all or part of the surface of a sphere or spheroid upon a plane surface. The process is one of transferring points on the surface of the sphere or spheroid onto a plane, or onto a developable surface (one that can be flattened to form a plane) such as a cylinder or cone. If points on the surface of the sphere or spheroid are projected from a single point (including infinity), the projection is said to be perspective or geometric. Most map projections are not perspective.

Selecting a projection,-- Each projection has distinctive features which make it preferable for certain uses, no one projection being best for all conditions. These distinctive features are most apparent on charts of large areas. As the area becomes smaller, the differences between various projections become less noticeable until on the largest scale chart, such as of a harbor, all projections become practically identical. Some of the desirable properties are:

1. *True shape* of physical features.
2. *Correct angular relationship*. A projection with this characteristics is said to be conformal or orthomorphic.
3. *Equal area*, or the representation of areas in their correct relative proportions.
4. *Constant scale* values for measuring distances.

5. *Great circles* represented as straight lines.
6. *Rhumb lines* represented as straight lines.

It is possible to preserve any one and sometimes more than one property in any one projection, but it is impossible to preserve all of them. For instance, a projection cannot be both conformal and equal area, nor can both great circles and rhumb lines be represented as straight lines.

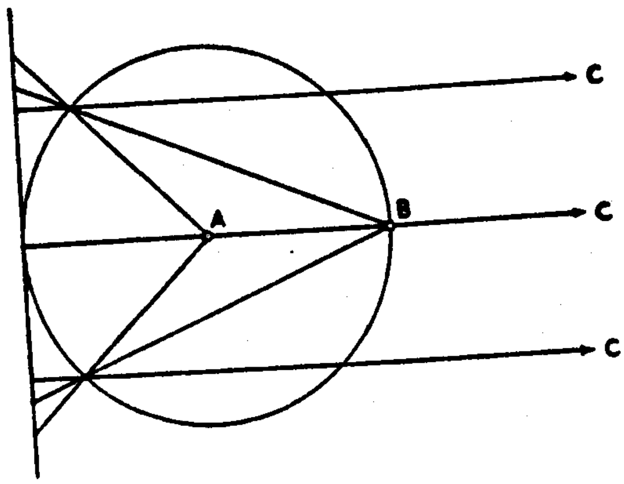
Types of projection. --Projections are usually classified primarily as to the type of developable surface to which the spheroidal surface is transferred. They are sometimes further classified as to whether the projection (but not necessarily the charts made by it) is centered on the equator (equatorial), a pole (polar), or some point or line between (oplique). The name of a projection often indicates its type and sometimes, in addition, its principal feature.

The projection used most frequently by mariners is commonly called Mercator, after its inventor. Classified according to type this is a conic projection upon a plane, the cylinder conceived as being tangent along the equator. A similar projection based upon a cylinder tangent along a meridian is called transverse Marcator or transverse orthomorphic. It is sometimes called inverse Mercator or inverse orthomorphic. If the cylinder is tangent along a great circle other than the equator or a meridian, the projection is called oblique Mercator or oblique orthomorphic.

In a simple conic projection points on the surface of the earth are conceived as transferred to a tangent cone. In a Lambert conformal projection the cone intersects the earth (a secant cone) at two small circles. In a polyconic projection, a series of tangent cones is used.

An azimuthal or zenithal projections is one in which points on the earth are transferred directly to a plane. If the origin of the projecting rays is the center or the earth, a gnomonic projection results; if the point opposite the plan's point of tangency, a stereographic projection; and if at infinity (the projecting lines being parellel to each other), an orthographic projection (the following figure). The gnomonic, stereographic, and orthographic are perspective projections. In an azimuthal equidistant

projection, which is not perspective, the scale of distances is constant along any radial line from the point of tangency.



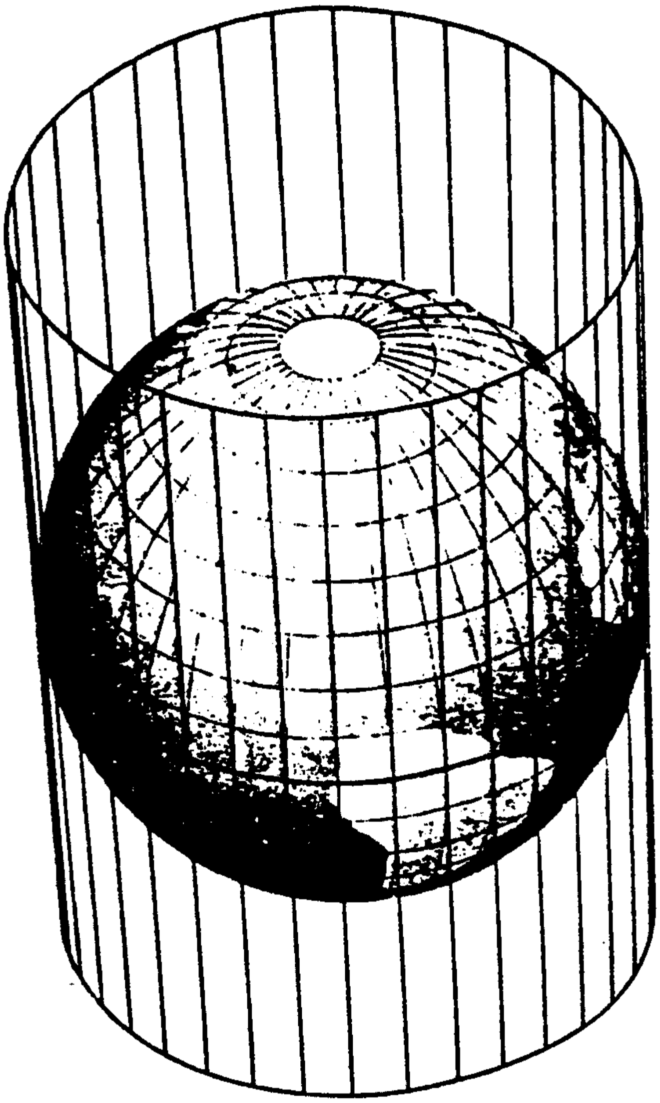
Azimuthal projections: A, gnomonic; B, stereographic; C (at infinity), orthographic.

Cylindrical and plane projections can be considered special cases of conical projections with the heights infinity and zero, respectively.

A graticule is the network of latitude and longitude lines laid out in accordance with the principles of any projection.

Cylindrical Projections

Features. – If a cylinder is placed around the earth, tangent along the equator, and the planes of the meridians are extended, they intersect the cylinder in a number of vertical lines (the following figure). These lines, all being vertical, are parallel, or everywhere equidistant from each other, unlike the terrestrial meridians, which become closer together as the latitude increases. On the earth the parallels of latitude are perpendicular to the meridians, forming circles of progressively smaller diameter as the latitude increases. On the cylinder they are shown perpendicular to the project meridians, but because a cylinder is everywhere of the same diameter, the projected parallels are all the same size.



A cylindrical projection

If the cylinder is cut along a vertical line (a meridian) ands spread out flat, the meridians appears as equally spaced, vertical lines, and the parallels as horizontal lines. The spacing of the parallels relative to each other differs in the various types of cylindrical projections.

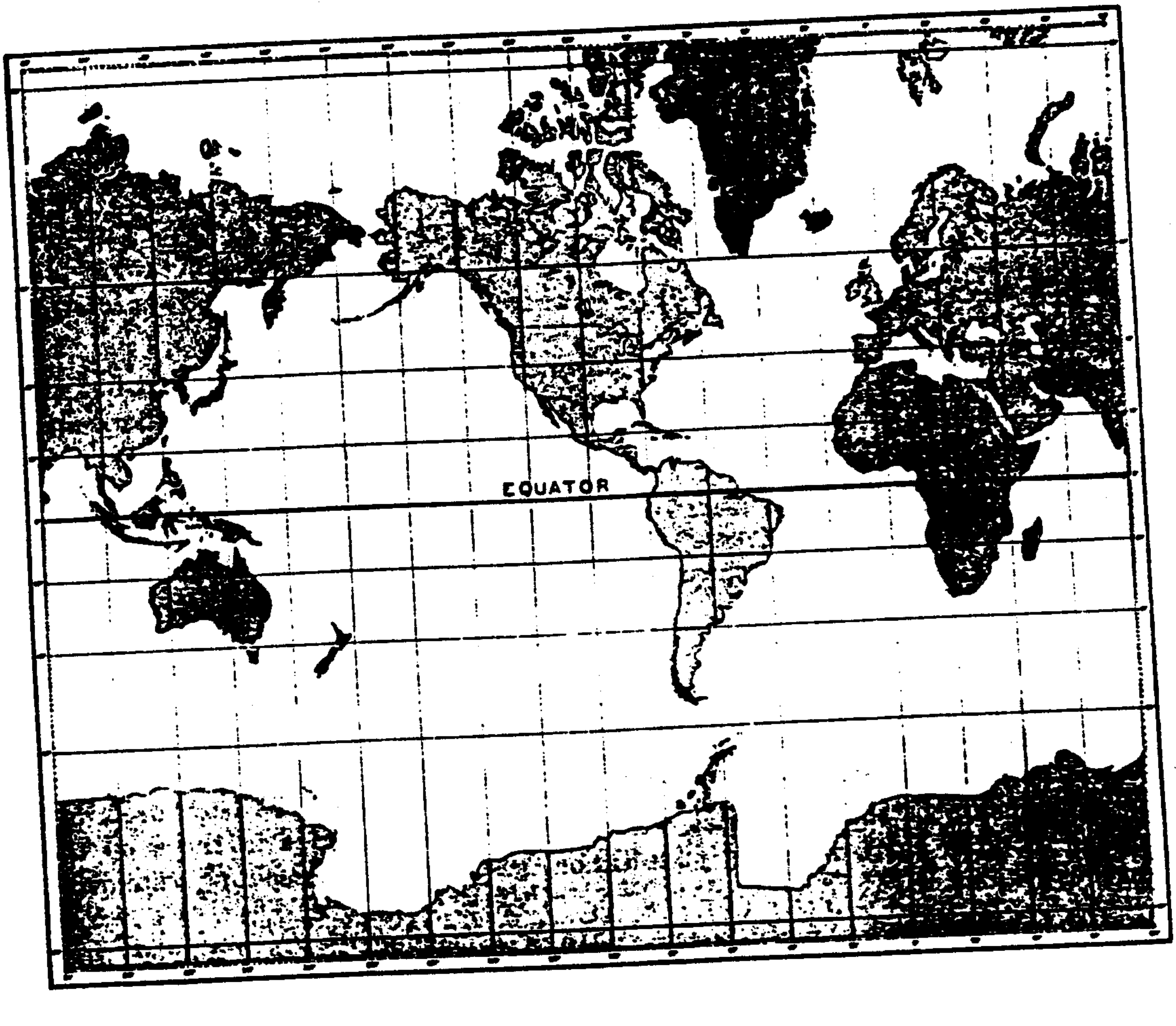
The cylinder may be tangent along some great circle other than the equator, forming an oblique or transverse cylindrical projection, on which the pattern of latitude and longitude lines appears quite different, since the line of tangency and the equator no longer coincide.

Mercator projection. --- A conformal projection upon a plane used for navigation is the **Mercator**, named for its inventor Gerhard Kremer (Mercator), a Flemish geographer. It is not perspective and the parallels cannot be located by geometrical projection, the spacing being derived mathematically. The use of a tanget cylinder to explain the development of the projection has been used, but the relationship of the terrestrial latitude and longitude lined to those on the cylinder is often carried beyond justification, resulting in misleading statements and illustrations.

The distinguishing feature of the Mercator projection (the following figure) among other projections is that both the meridians and parallels are expanded at the same ratio with increased latitude. The expansion is equal to the secant to the latitude, with a small correction for the ellipticity of the earth. Since the secant of 90° is infinity, the projection cannot include the poles. Expansion is the same in all direction and angles are correctly shown, the projection being conformal. Rhumb lines appear as straight lines, the directions of which can be measured directly on the chart. Distances can also be measured directly, to practical accuracy, but not by a single distance scale over the entire chart, unless the spread of latitude is small. The latitude scale is customarily used for measuring distances, the expansion of the scale being the same as that of distances at the same latitude. Great circles, except meridians and the equator, appear as curved lines concave to the equator. Small areas appear in their correct shape but of increased size unless they are near the equator. Plotting of positions by latitude and longitude is done by means of rectangular coordinates, as on any cylindrical projection.

Meridional parts.—At the equator a degree pf longitude is approximately equal in length to a degree of latitude. As the distance from the equator increases, degree of latitude remain approximately the same (not exactly because the earth is not quite a sphere), while degrees of longitude become progressively shorter. Since degrees of longitude appear everywhere he same length in the Mercator projection, it is

necessary to increase the length of the meridians if the expansion is to be equal in all directions. Thus, to maintain the correct proportions between degrees of latitude and degrees of longitude, the former are shown progressively longer as the distance from the equator increases (the following figure).



A Mercator map of the world

The length of the meridian, as thus increased between the equator and any given latitude, expressed in minutes of the equator as a unit, constitutes the number of meridional parts (M) corresponding to that latitude. Meridional parts given in table 5 for every minute of latitude from the equator to the pole, afford facilities for constructing a Mercator chart and for solving problems in Mercator sailing. These values are for the WGS ellipsoid of 1972. The formula for meridional parts, given in the explanation to table 5, is derived from an integral representing the exact relationship.

Mercator chart construction. – To construct a Mercator chart, first select the scale and then proceed as follows:

Draw a series of vertical lines to represent the meridians, spacing them in accordance with the scale selected. If the chart is to include the equator, the distances of the various parallels from the equator are given directly in table 5, although it may be desirable to convert the tabulated values to more convenient units. Thus, if 1°(60') of longitude is to be shown as 1 inch, each meridional part will be $^1/_{60}$ or 0.01667 inch in length. The distance, in inches, of any parallel from the equator is then determined by dividing its meridional parts by 60 or multiplying them by 0.01667.

If the equator is not to be included, the meridional difference (m) is used. This is the difference between the meridional parts of the various and that of the lowest parallel (the one nearest the equator) to be shown. Distances so determined are measured from the lowest parallel.

It is often desired to show a minimum area on a chart of limited size, to the largest possible scale. The scale is then dictated by the limitations.

When the graticule has been completed, the features to be shown are located by means of the latitude and longitude scales.

Example. — A Mercator chart is to be constructed at thew maximum scale on a sheet of paper 35 × 46 inches, with a minimum 2-inch margin outside the neatline limiting the charted area. The minimum area to be covered is lat. 44° - 50° north and long. 56° - 68° west.

Solution. – *Step one:* Determine which dimension to place horizontal. From table 5 the meridional difference is:

The chart is to cover at least 12° (86° - 56°) of longitude. The longitude is therefore to cover a distance of 12×60 = 720 meridional parts. Since there are a greater number of meridional parts of longitude to be shown than of latitude, the long dimension is placed horizontal.

Step two: Determine whether the latitude or longitude is the limiting scale factor. The number of inches available for latitude coverage is 31 (35 inches minus a 2-inch margin top and bottom). If 527 meridional parts are to be shown in 31 inches, each meridional part will be

$$\frac{31}{527} = 0.05882 \text{ inch}$$

There are 46 –4 = 42 inches for longitude, and therefore the length of each meridional part will be

$$\frac{42}{720} = 0.05833 \text{ inch}$$

Thus, the longitude is the limiting scale factor, for all of the desired area could not be shown in the available space if the larger scale were to be used. Using the smaller scale, it is found that 30.74 inches (0.05833×527) will be needed to show the desired latitude coverage. The top and bottom margins can be increased slightly, or additional latitude coverage can be shown. If it is desired to include the additional coverage, the amount can be determined by dividing the available space, 31 inches, by the scale, 0.05833. This is 531.5 meridional parts, or 4.5 more than the minimum. By inspection of table 5, it is seen that the latitude can be extended either 3'.3 below 44° or2'.9 above 50°. Suppose it is decided that the margin will be increased slightly and only the desired minimum coverage shown.

Step three: Determine the spacing of the meridians and parallels. Meridians 1° or 60' apart will be placed 60×0.05833=3.50 inches apart. Next, determine each degree of latitude separately. First, compute the meridional difference between the lowest parallel and the various parallels to be shown:

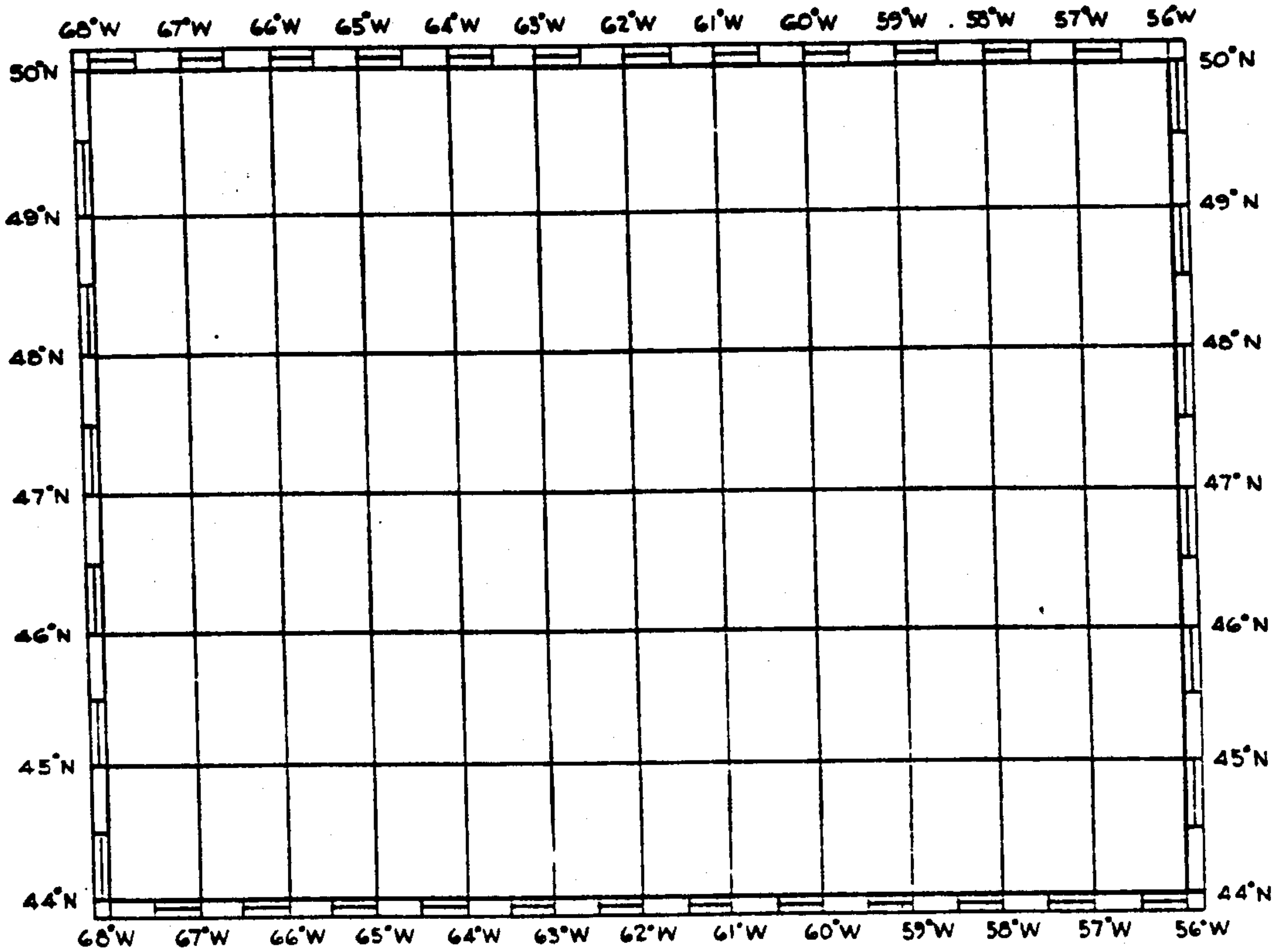
Next, determine the distance of each parallel from that of L 44°N by multiplying its meridional difference by the scale, 0.05833:

Step four: Draw the graticule. Draw a horizontal line 2.13 inches.

from the bottom. This is the lower neatline. Label it "44°N". Draw the right-hand neatline 2 inches from the edge. Label it "56°W". Along the lower parallel measure off distances in units of 3.50 inches from λ 56°W at the right to λ 68°W at the left. Through the points thus located draw vertical lines to represent the meridians. Along any meridian measure upward from the horizontal line a series of distances as determined by the calculations above. Through these points draw horizontal lines to represent the parallels. Label the meridians and parallels as shown in the following figure.

Step five: Make off the latitude and longitude scales around the neatline. The scales can be graduated in units as small as desired. Determine the longitude scale by dividing the degrees into equal parts. Establish the latitude scale by computing each subdivision of a degree in the same manner as described above for whole degrees. In low latitude degrees of latitude can be divided into equal parts without serious loss of accuracy.

Step six: Fill in the desired detail.



The graticule of a Mercator chart from L 44°N to L 50°N and from λ 56°W to λ 68°W.

In *south* latitude the distance between consecutive parallels increase toward the *south*. The top parallel is drawn first and distances measured downward from it. Latitude labels increase toward the *south* (down).

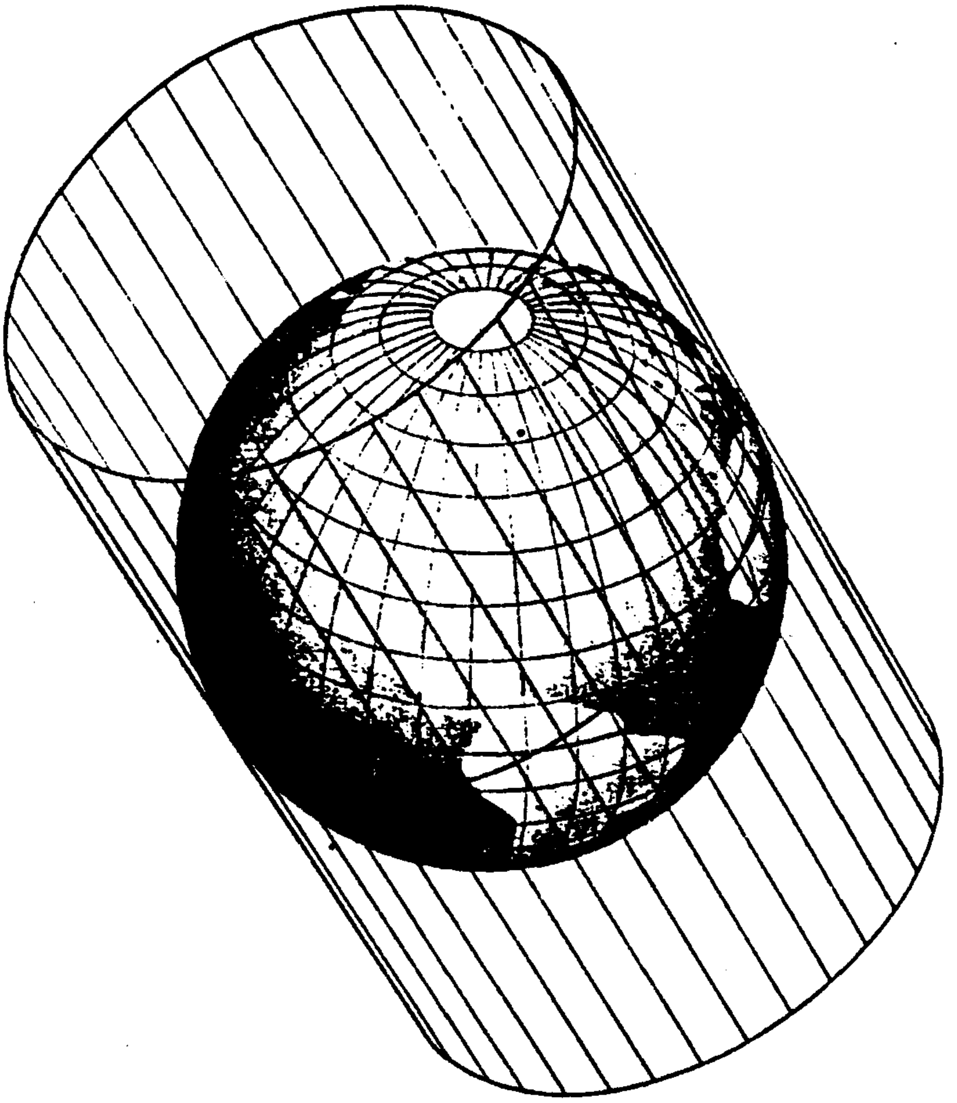
In east longitude the longitude labels increase toward the east (right).

Transverse and oblique Mercator projections. --- If Mercator principles are used to construct a chart, but with the cylinder tangent along a meridian, a transverse Mercator or transverse orthomorphic projection results. The word "inverse" is sometimes used in place of "transverse" with the same meaning. If the cylinder is tangent at some great circle other than the equator or a meridian (the following figure), the projection is called oblique Mercator or oblique orthomorphic. These

projections utilize a fictitious graticule similar to but offset from the familiar network of meridians and parallels. The tangent great circle is the fictitious equator. Ninety degrees from it are two fictitious poles. A group of great circles through these poles and perpendicular to the tangent great circle are the fictitious meridians, while a series of circles parallel to the plane of the tangent great circle form the fictitious parallels.

The actual meridians and parallels appear as curved lines (the following figures). A straight line on the transverse or oblique Mercator projection makes the same angle with all fictitious meridians, but not with the terrestrial meridians. It is therefore a **fictitious rhumb line**. Near the tangent great circle a straight line closely approximates a great circle. It is in this area that the chart is most useful.

The **Universal Transverse Mercator (UTM) grid** is a military grid superimposed upon a transverse Mercator graticule, or the representation of these grid lines upon any graticule.



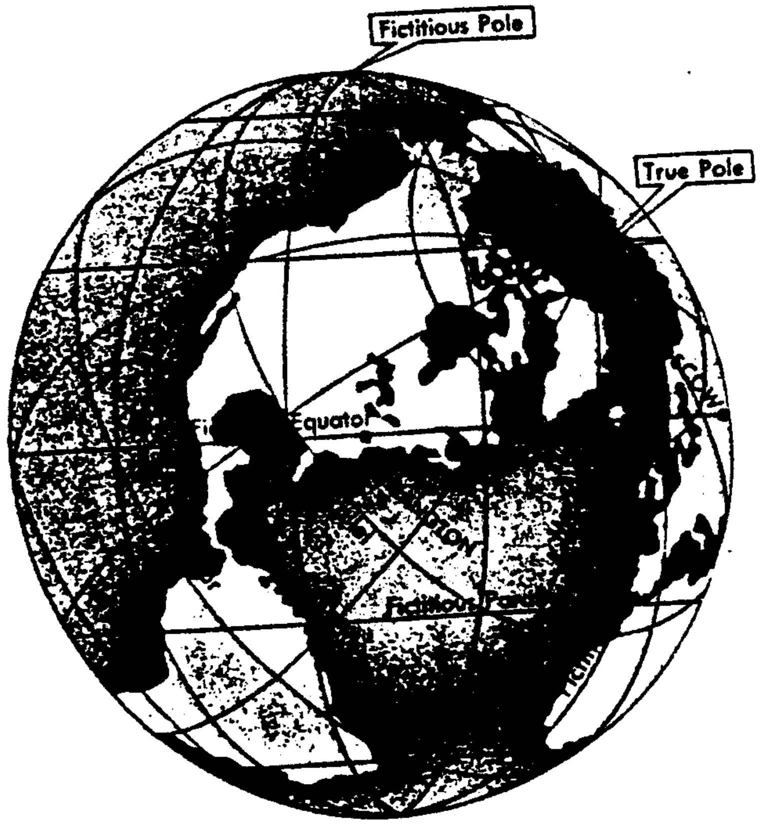
An oblique Mercator projection.

This grid system and these projections are often used for large-scale (harbor) nautical charts and military charts.

Transverse Mercator projection. –A special case of the Mercator projection in which the cylinder is tangent along a meridian is called a transverse (inverse) Mercator or transverse (inverse) orthomorphic projection. Since the area of minimum distortion in near a meridian, this projection is useful for charts covering a large band of latitude and

extending a relatively short distance on each side of the tangent meridian (the following figure). It is sometimes used for star charts showing the evening sky at various seasons of the year.

Oblique Mercator projection . – The Mercator projection in which the cylinder is tangent along a great circle other than the equator or a meridian is called an oblique Mercator or oblique orthomorphic projection. This projection is used principally where it is desired to depict an area in the near vicinity of an oblique great circle, as, for instance, along the great-circle route between two important, widely separated centers. Figure (Page 79) is a Mercator map showing Washington and Moscow and the great circle joining them. Figure (Page 80) is an oblique Mercator map with the great circle between these two centers as the tangent great circle or fictitious equator as in the following figure. The limits of the chart of figure (Page 80) are indicated in the figure after this one. Note the large variation in scale as the latitude changes.



The fictitious graticule of an oblique Mercator projection.

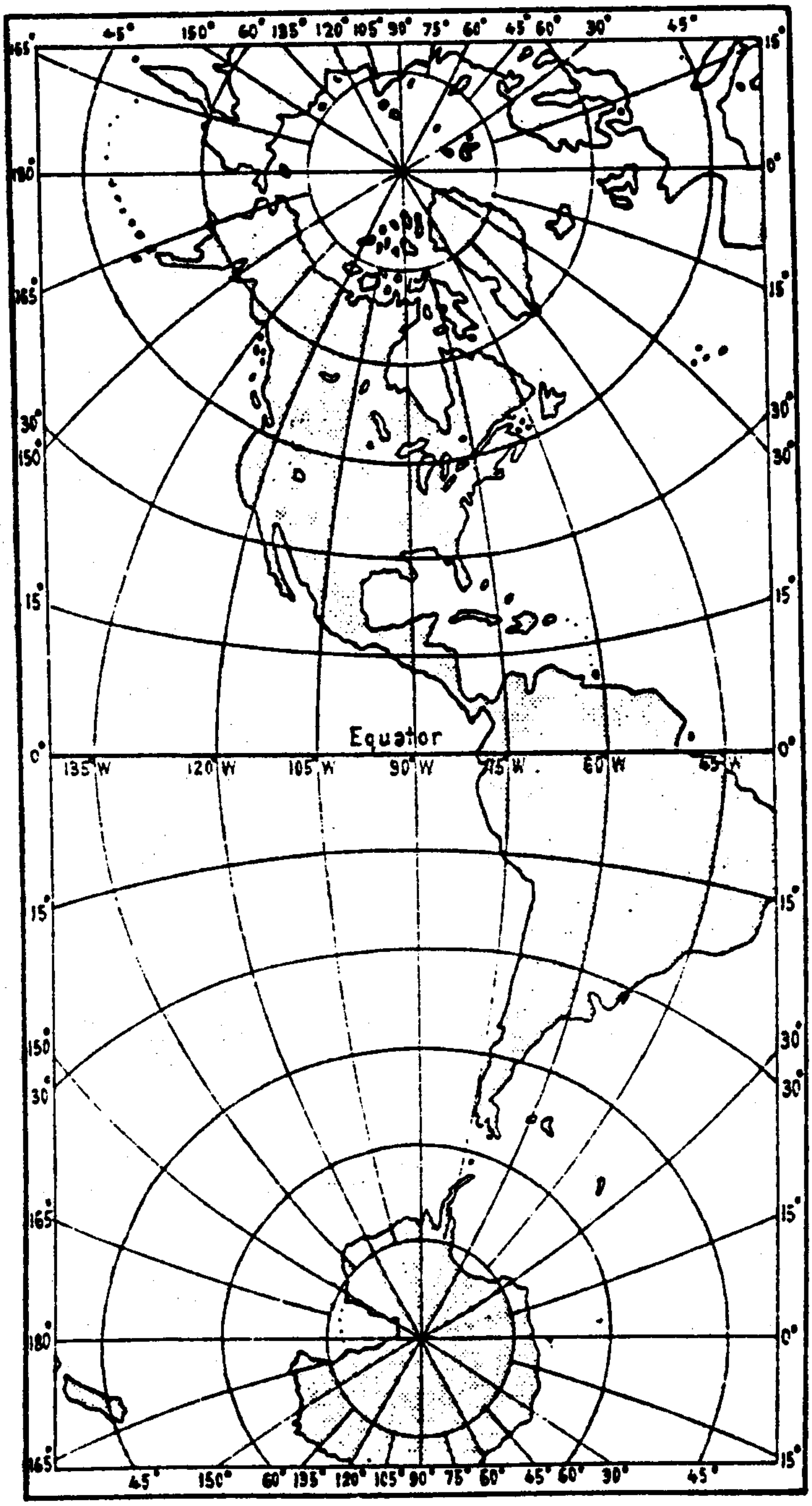
Rectangular projection. – A cylindrical projection similar to the Mercator but with uniform spacing of the parallels is called a rectangular projection (Page 81). It is convenient for graphically depicting information where distortion is not important. The principle navigational use of this projection is for the star chart of the *Air Almanac*, where positions of stars are plotted by rectangular coordinates representing declination (ordinate) and sidereal hour angle (abscissa). Since the meridians are parallel, the parallels of latitude (including the equator and the poles) are all represented by lines of equal length.

Conic Projections

Features.—A conic projection is produced by transferring points from the surface of the earth to a cone or series of cones which are then cut along an element and spread out flat to form the chart. If the axis of the cone coincides with the axis of the earth, the usual situation, the parallels appear as arcs of circles and the meridians as either straight or curved lines converging toward the nearer pole. Excessive distortion is usually avoided by limiting the area covered to that part of the cone near the surface of the earth. A parallel along which there is no distortion is called a **standard parallel**. Neither the transverse conic projection, in which the axis of the cone is in the equatorial plane, nor the oblique conic projection, in which the axis of the cone is oblique to the plane of the equator, are ordinarily used for navigation, their chief use being for illustrated maps.

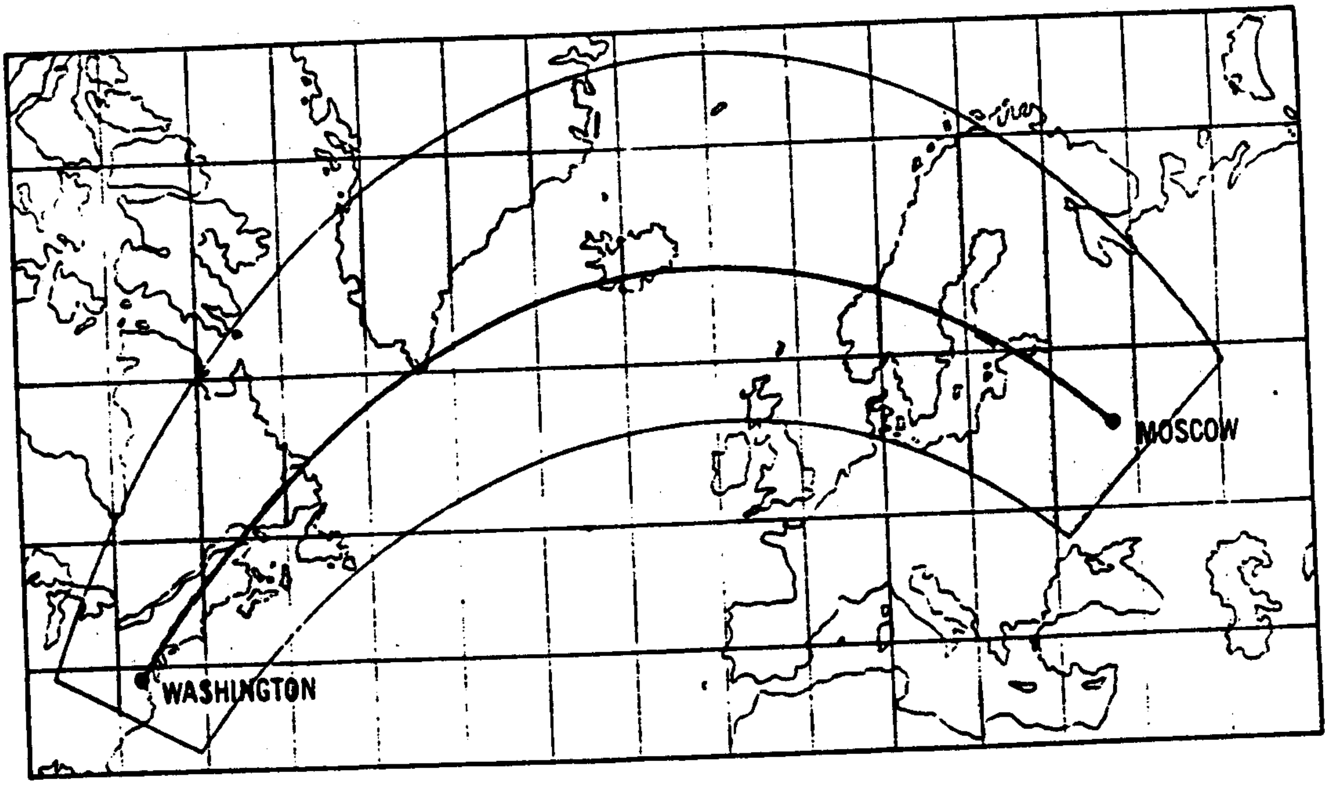
The appearance and features of conic projections are varied by using cones tangent at various parallel, using a secant (intersecting) cone, or by using a series of cones.

Simple conic projection. – A conic projection using a single tangent cone is called a **simple conic** projection (Page 82). The height of the cone increases as the latitude of the tangent parallel decreases. At the equator the height reaches infinity and the cone becomes a cylinder. At the pole its height is zero and it becomes a plane. As in the Mercator projection, the simple conic projection is not

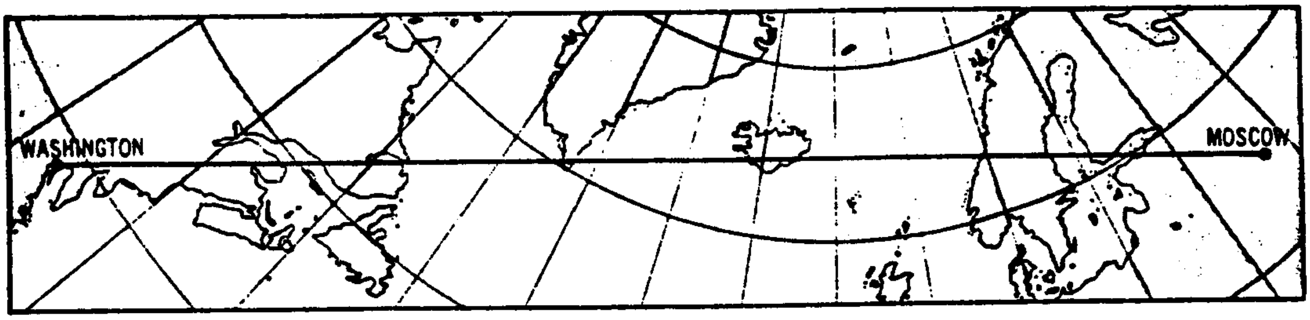


A transverse Mercator map of the Western Hemisphere.

perspective, as only the meridians are projected geometrically, each becoming an element of the cone. When this is spread out flat to form a map; the meridians appear as straight lines converging at the apex of the cone. The standard parallel, or that at which the cone is tangent to the earth, appears as the arc of a circle with its center at the apex of the cone, or the common point of intersection of all the meridians. The other parallels are concentric circle, the distance along any meridian between consecutive parallels being in correct



The great circle between Washington and Moscow as it appears on Mercator map.

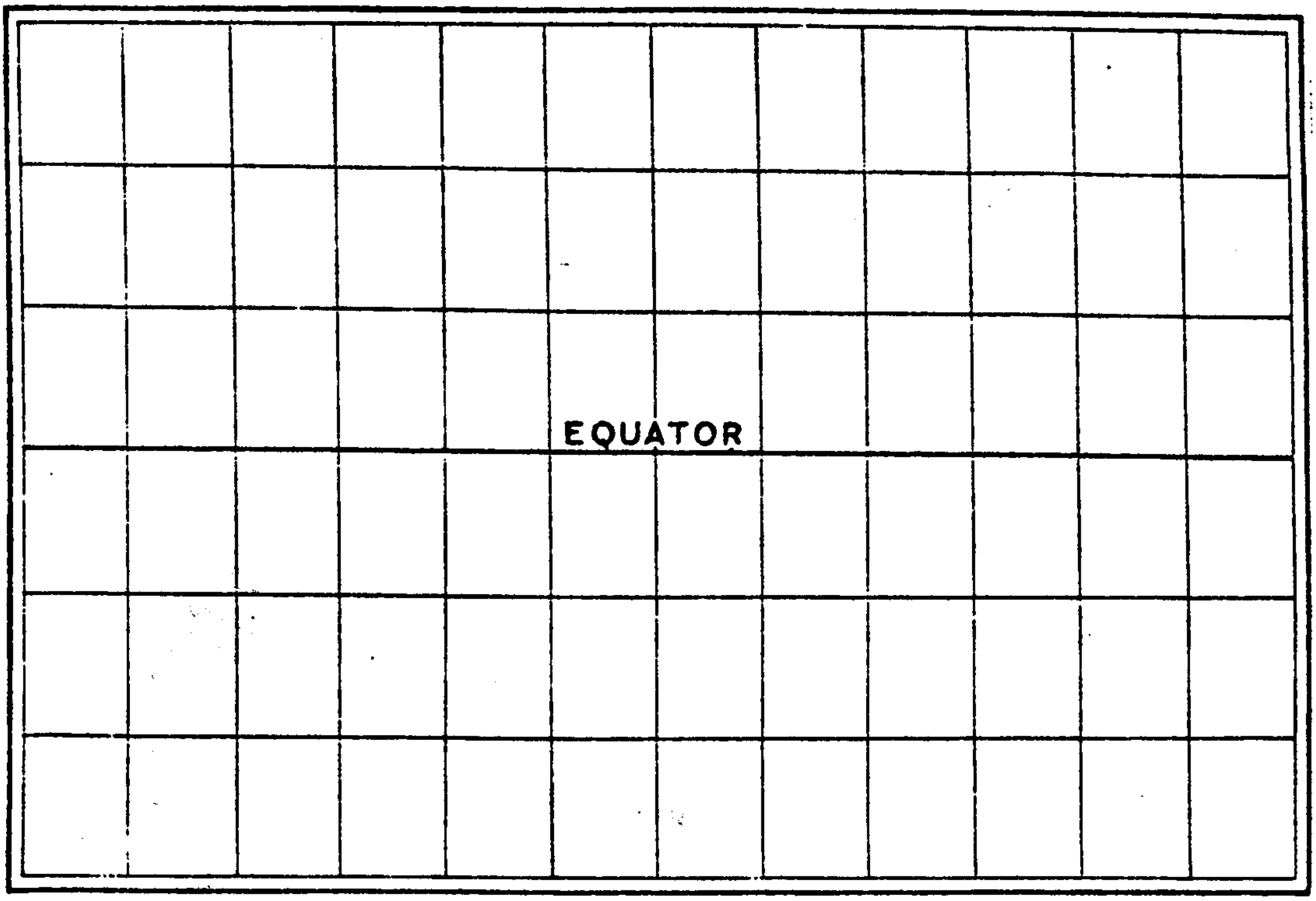


An oblique Mercator map based upon a cylinder tangent along the great circle through Washington and Moscow. The map includes an area 500 miles on each side of the great circle. The limits of this map are indicated on the Mercator map of figure 310a

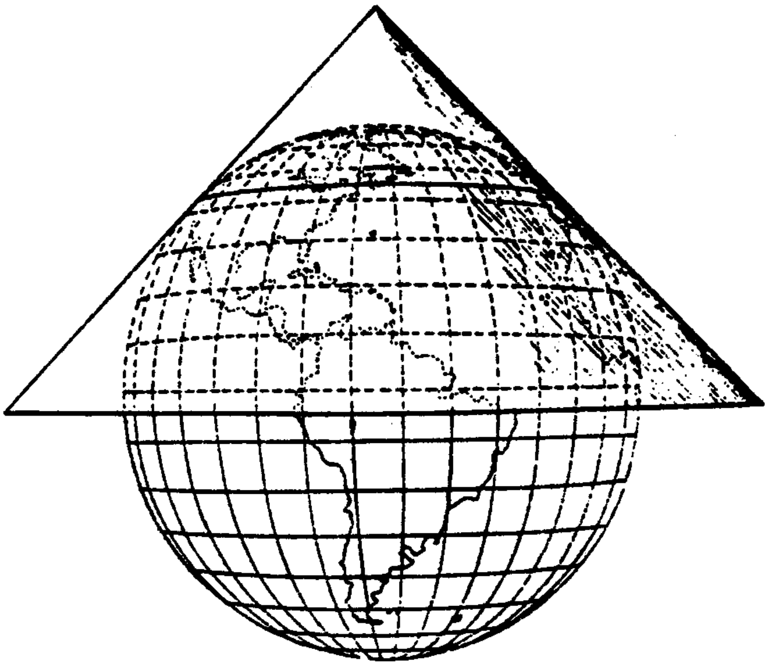
relation to the distance on the earth, and hence derived mathematically. The pole is represented by a circle (Page 83). The scale is correct along any meridian and along the standard parallel. All other parallels are too great in length, the error increasing with increased distance from the standard parallel. Since the scale is not the same in all directions about every point, the projection is not conformal, its principle disadvantage for navigation. Neither is it an equal-area projection.

Since the scale is correct along the standard parallel and varies uniformly on each side, with comparatively little distortion near the standard parallel, this projection is useful for mapping an area covering a large spread of longitude and a comparatively narrow band of latitude. It was developed by Claudius Ptolemy in the second century after Christ to map just an area, the Mediterranean.

Lambert conformal projection.—The useful latitude range of the simple conic projection can be increased by using a secant cone interesting the earth at two standard parallels (Page 84.). The area between the two standard parallels is compressed, and that beyond is expanded. Such a projection is called a secant conic or **conic projection with two standard parallels.**

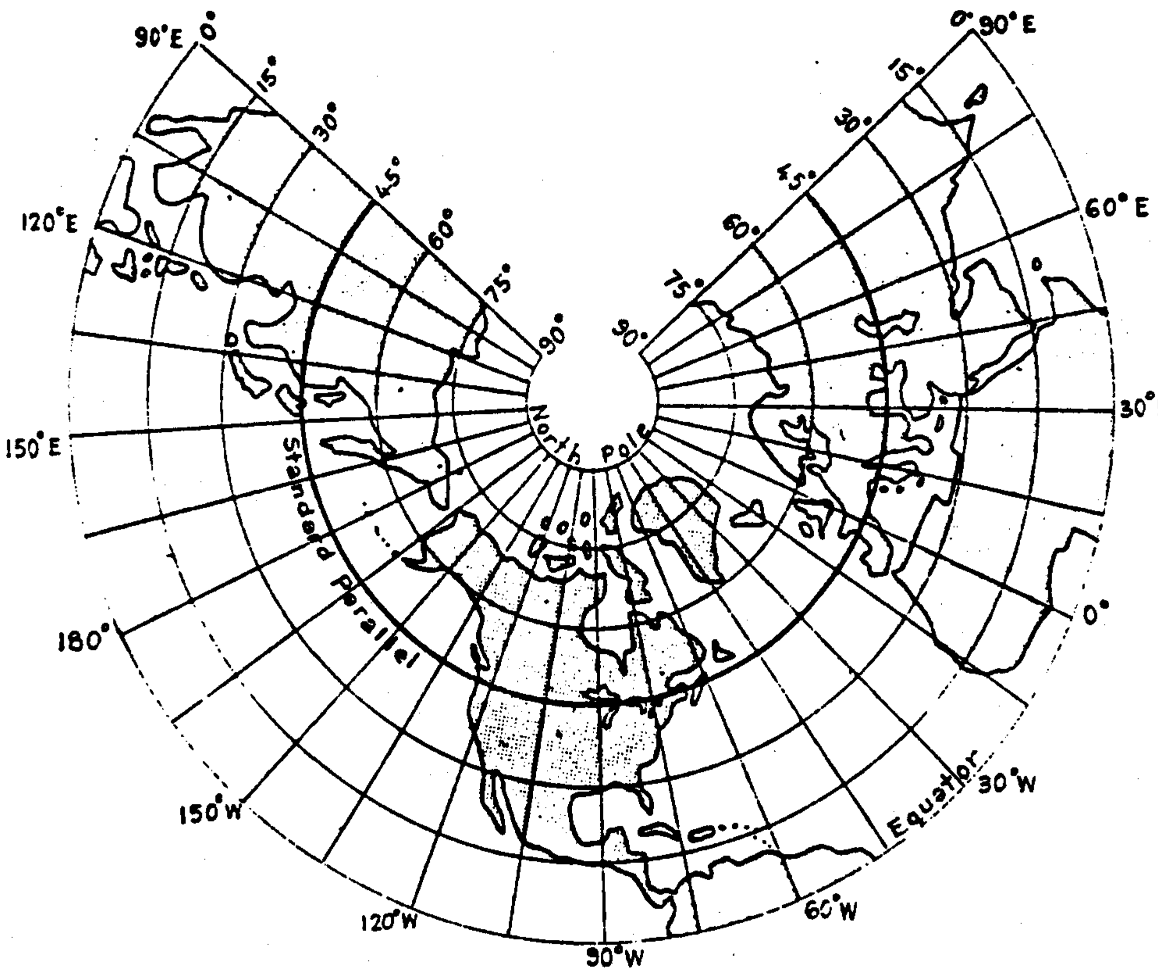


A rectangular graticule.



A simple conic projection.

If, in such a projection, the spacing of the parallel is altered so that the distortion is the same along them as along the meridians, the projection becomes conformal. This is known as the Lambert conformal projection, after its eighteenth century Alsatian inventor, Johann Heinrich Lambert. It is the most widely used conic projection for navigation, though its use is more common among aviators than mariners. Its appearance is very much the same as that of the simple conic projection. If the chart is not carried far beyond the standard parallels, and if these are not a great distance apart, the distortion over the entire chart is small.

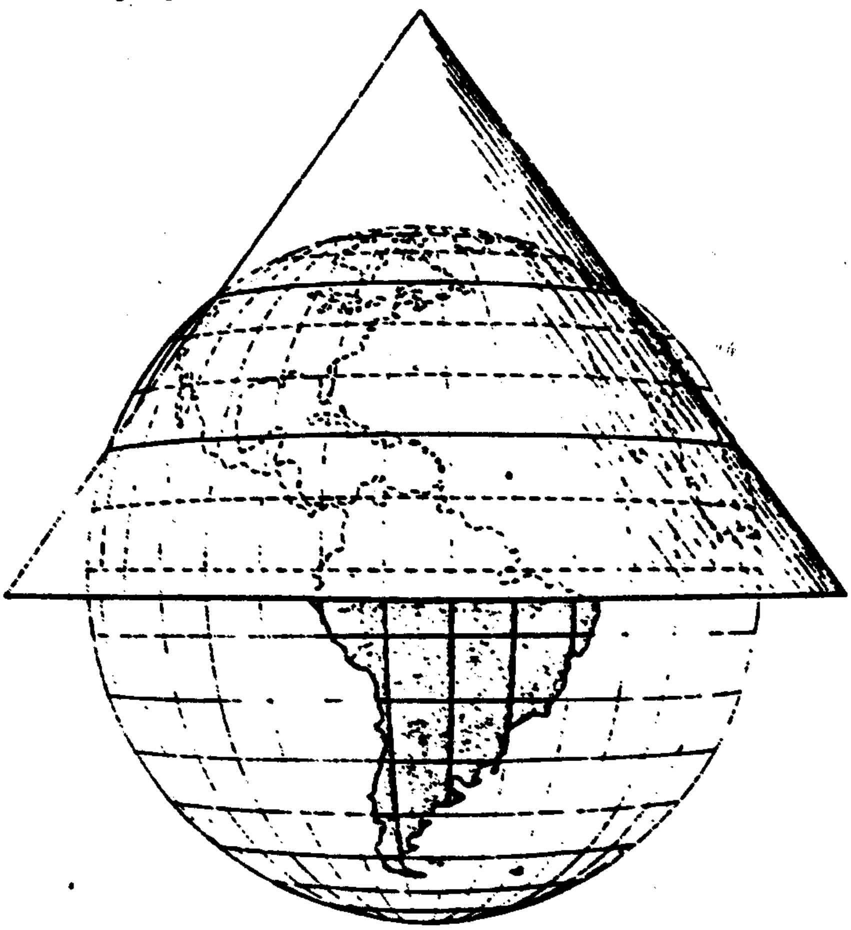


A simple conic map of the Northern Hemisphere.

Astraight line on this projection so nearly approximates a great circle that the two can be considered identical for many purposes of navigation. Radio bearings, from signals which are considered to travel great circle, can be plotted on this projection without the correction needed when they are plotted on a Mercator chart. This feature, gained without sacrificing conformality, has made this projection popular for aeronautical charts, since aircraft make wide use of radio aids to navigation. It has made little progress in replacing the Mercator projection for marine navigation, except in high latitude. In a slightly modified form this projection has been used for polar charts.

Polyconic projection.—The latitude limitations of the secant conic projection can be essentially eliminated by the use of a series of cones, resulting in a polyconic projection. In this projection each parallel is the base of a tangent cone. At the edges of the chart the area between parallels is expanded to eliminate gaps. The scale is correct along any parallel and along the central meridian of the projection. Along other meridians the scale increases with increased difference of longitude from the central meridian. Parallels appear as nonconcentric circles and meridians as curved lines converging toward the pole and concave to the central meridian.

The polyconic projection is widely used in atlases, particularly for areas of large range in latitude and reasonably large range in longitude, as for a continent such as North America. However, since it is not conformal, this projection is not customarily used in navigation.



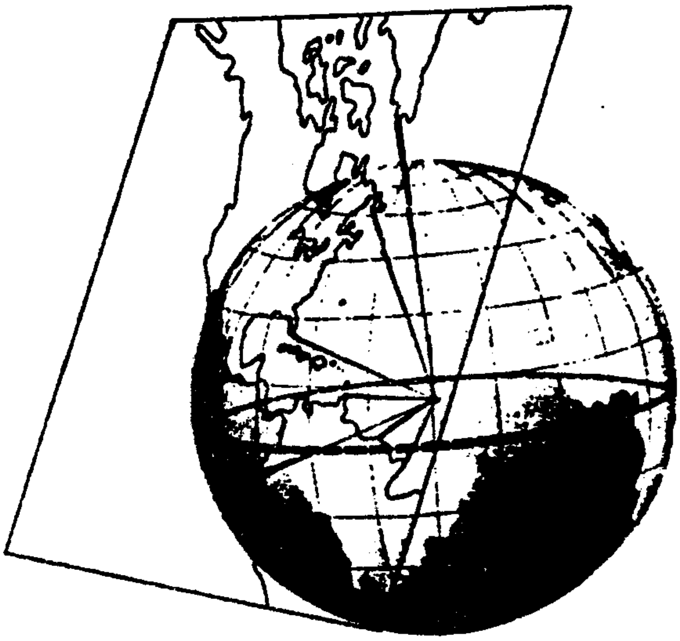
A secant cone for a conic projection with two standard parallels.

Features. --If points on the earth are projected directly to a plane surface, a map id formed at once, without cutting and flattening, or " developing". This can be considered a special case of a conic projection in which the cone has zero height.

The similar case of the azimuthal projection is one in which the plane is tangent at one of the poles. The meridians are straight lines intersecting at the pole, and the parallels are concentric circles with their common center at the pole. Their spacing depends upon the method of transferring points from the earth to the plane.

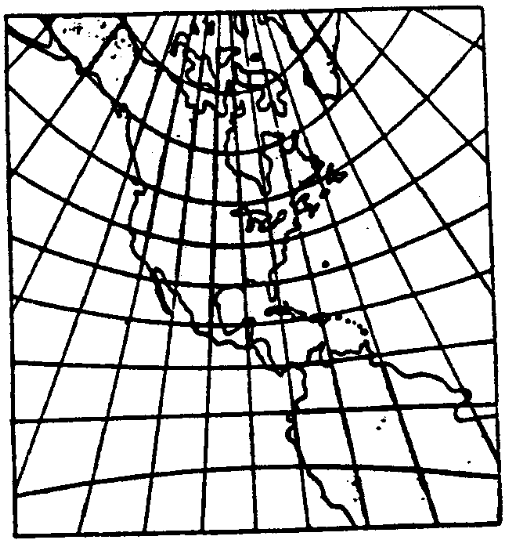
If the plane is tangent at some point other than a pole, straight lines through the point of tangency are great circles, and concentric circles with their common center at the point of tangency connect points of equal distance from that point. Distortion, which is zero at the point of tangency, increases along any great circle through this point. Along any circle whose center is the point of tangency, the distortion is constant. The bearing of any point from the point of tangency is correctly represented. It is for this reason that these projections are called azimuthal. They are also called zenithal. Serval of the common azimuthal projections are perspective.

Gnomonic projection. – If a plane is tangent to the earth, and points are projected geometrically from the center of the earth, the result is a gnomonic projection (Page 86). This is probably the oldest of the projections, believed to have been developed by Thales about 600 BC. Since the projection is perspective, it can be demonstrated by placing a light at the center of a transparent terrestrial globe and holding a flat surface tangent to the sphere.



An oblique gnomonic projection.

For the oblique case the meridians appear as straight lines converging toward the nearer pole. The parallels, except the equator, appear as curves (the following figure). As in all azimuthal projections, bearing from the point



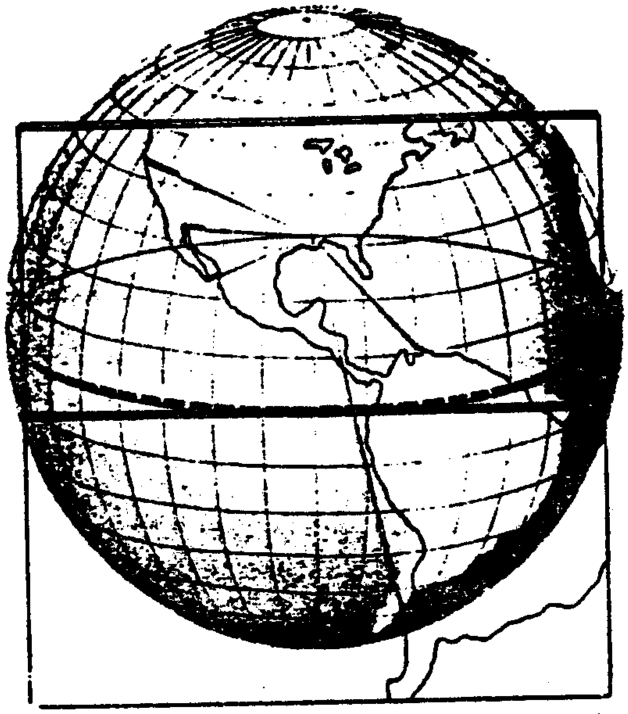
An oblique gnomonic map with point of tangency at latitude 30° N, longitude 90°W

Of tangency are correctly represented. The distance scale, however, changes rapidly. The projection is neither conformal nor equal area. Distortion is
so great that shapes, as well as distances and areas, are very poorly represented, except near the point of tangency.

The usefulness of the projection rests upon the one feature that *any* great circle appears on the map as a straight line. This is apparent when it is realized that a great circle is the line of intersection of a sphere and a plane through the center of the sphere, this center being the origin of the projecting rays for the map. This plane intersects any other nonparallel plane, including the tangent plane, in a straight line. It is this one useful feature that gives charts made on this projection the common name **great-circle charts.**

Gnomonic charts published by DMATHC bear instructions for determining direction and distance on the charts. The parallel navigational use of such charts is for plotting the great-circle track between points, for planning purposes. Points along the track are then transferred, by latitude and longitude, to the navigational chart, usually one on the Mercator projection. The circle is then followed approximately by following the rhumb line from one point to the next.

Stereographic projection.—If points on the surface of the earth are projected geometrically onto a tangent plane, from a point on the surface of the earth opposite the point of tangency, a **stereographic** projection results (see the following figure). It is also called an **azimuthal orthomorphic** projection.

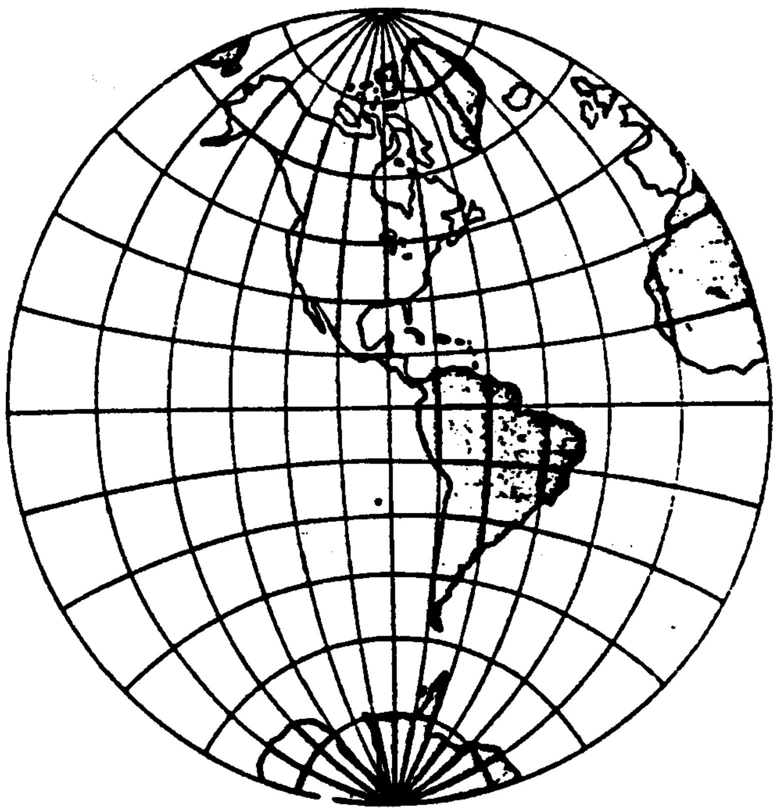


An equatorial stereographic projection.

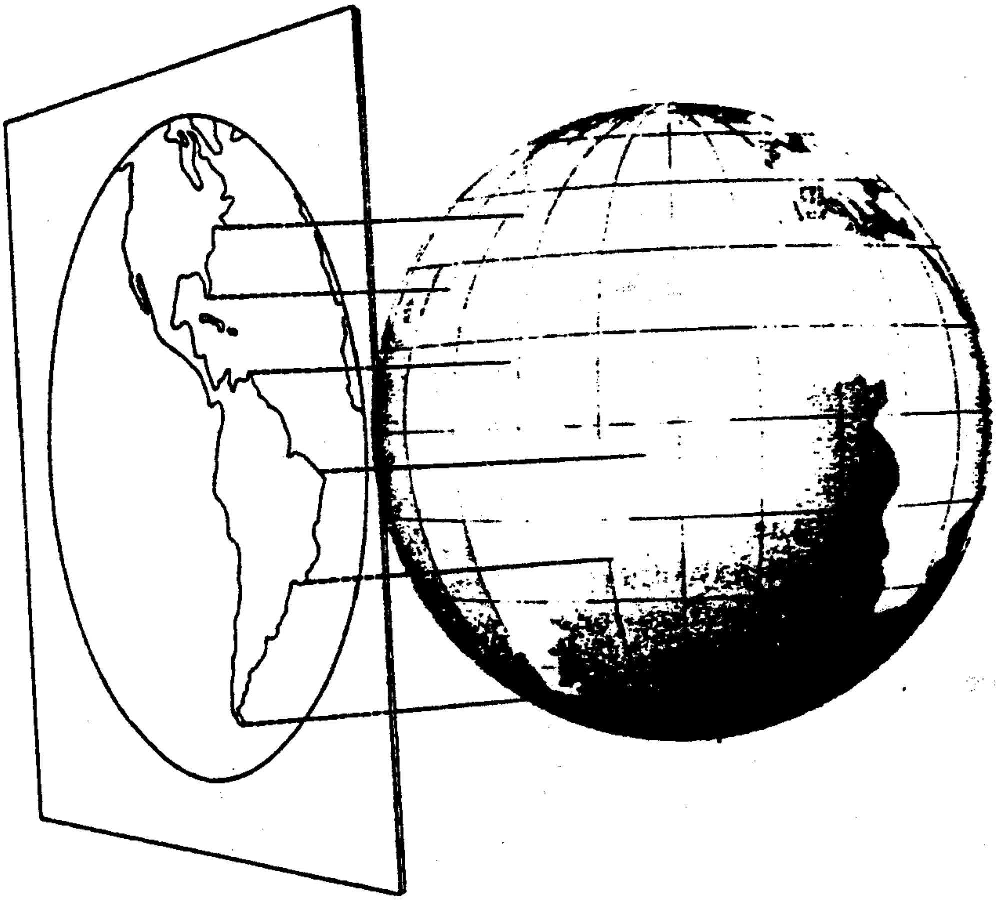
The scale of the stereographic projection increases with distance from the point of tangency, but more slowly than in the gnomonic projection. An entire hemisphere can be shown on the stereographic projection without excessive distortion (the above figure). As in other azimuthal projections, great circles through the point of tangency appear as straight lines. All other circles, including meridians and parallels, appear as circle or arcs of circles.

The principle navigational use of the stereographic projection is for charts of the polar regions and devices for mechanical or graphical solution of the navigational triangle. A Universal Polar Stereographic (UPS) grid, mathematically adjusted to the graticule is used as a reference system.

Orthographic projection.—If terrestrial points are projected geometrically from infinity (projecting lines parallel) to a tangent plane, an orthographic projection results (Page 88). This projection is neither conformal nor equal area and has no advantages as a map projection. Its principal navigational use is in the field of navigational astronomy, where it is useful for illustrating or graphically solving the navigational triangle and for illustrating celestical coordinates. If the plane is tangent at a point on the equator, the usual case, the parallels (including the equator)appear as straight lines and the meridians as ellipses, except that the meridian through the point of tangency appears as a straight line and the one 90° away as a circle (Page 91).



A stereographic map of the Western Hemisphere.



An equatorial orthographic projection.

Azimuthal equidistant projection. ---An azimuthal projection in which the distance scale along any great circle through the point of tangency is constant is called an azimuthal equidistant projection. If a pole is the point of tangency, the meridians appear as straight lines

and the parallels as concentric circles, equally spaced. If the plane is tangent at some point other than a pole, the concentric circles represent distance from the point of tangency. In this case meridians and parallels appear as curves. The projection can be used to portray the entire earth, the point 180° from the point of tangency appearing as the largest of the concentric circles. The projection is neither conformal nor equal area, nor is it perspective. Near the point of tangency the distortion is small, but it increases with distance until shapes near the opposite side of the earth are unrecognizable (Page 93).

An orthographic map of the Western Hemisphere.

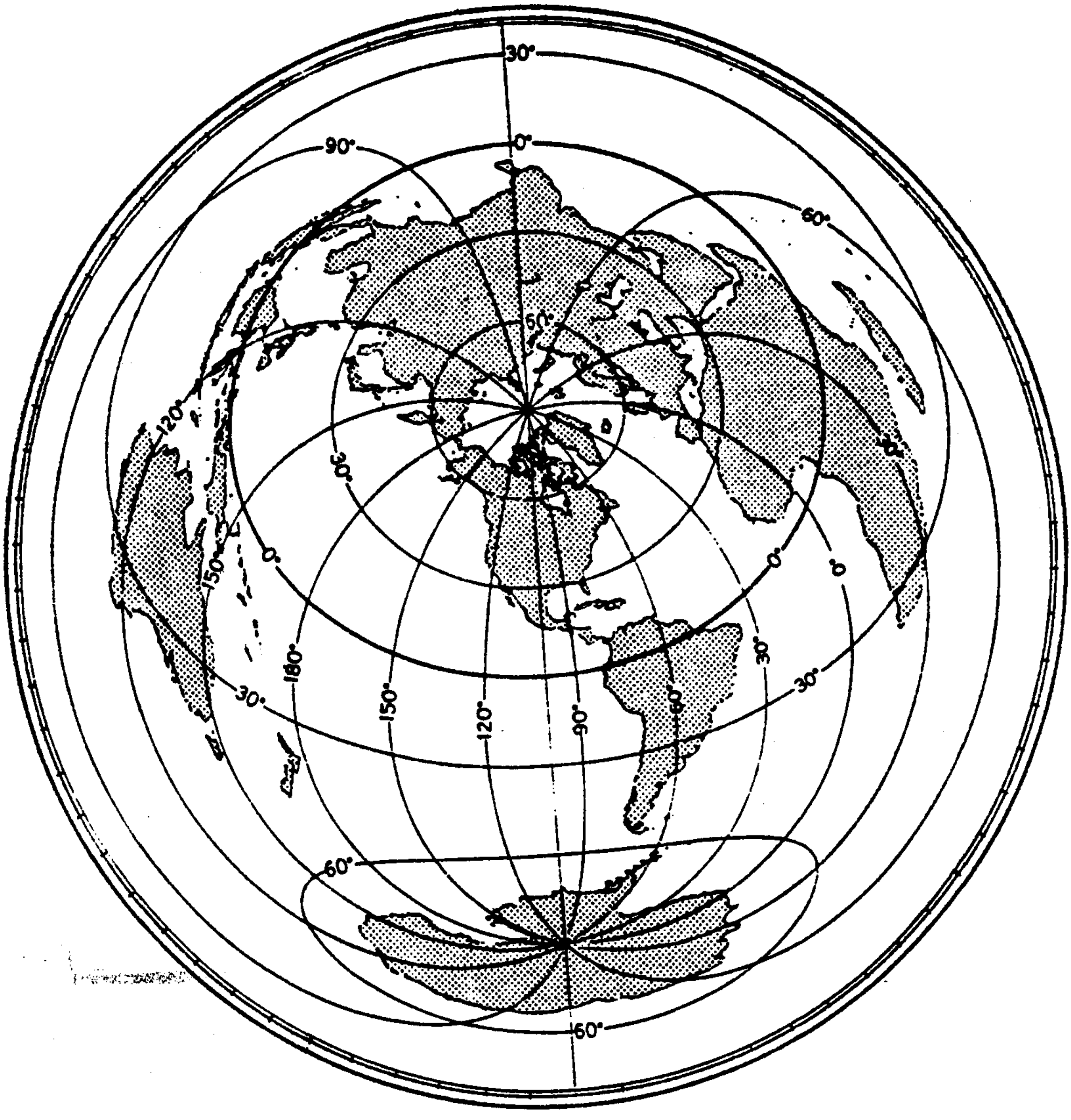
The projection is useful because it combines the three features of being azimuthal, having a constant distance scale from the point of tangency, and permitting the entire earth to be shown on one map. Thus, if an important harbor or airport is selected as the point of tangency, the great-circle course, distance, and track from that point to any other point

on the earth are quickly and accurately determined. For communication work at a fixed point, the point of tangency, the path of an incoming signal is at once apparent if the direction of arrival has been determined. The direction to train a directional antenna for desired results can be determined easily. The projection is also used for polar charts and for the familiar star finder and identifier, No. 2101-D.

Polar Charts

Polar projections. – Special consideration is given to the selection of projections for polar charts, principally because the familiar projections become special cases with unique features.

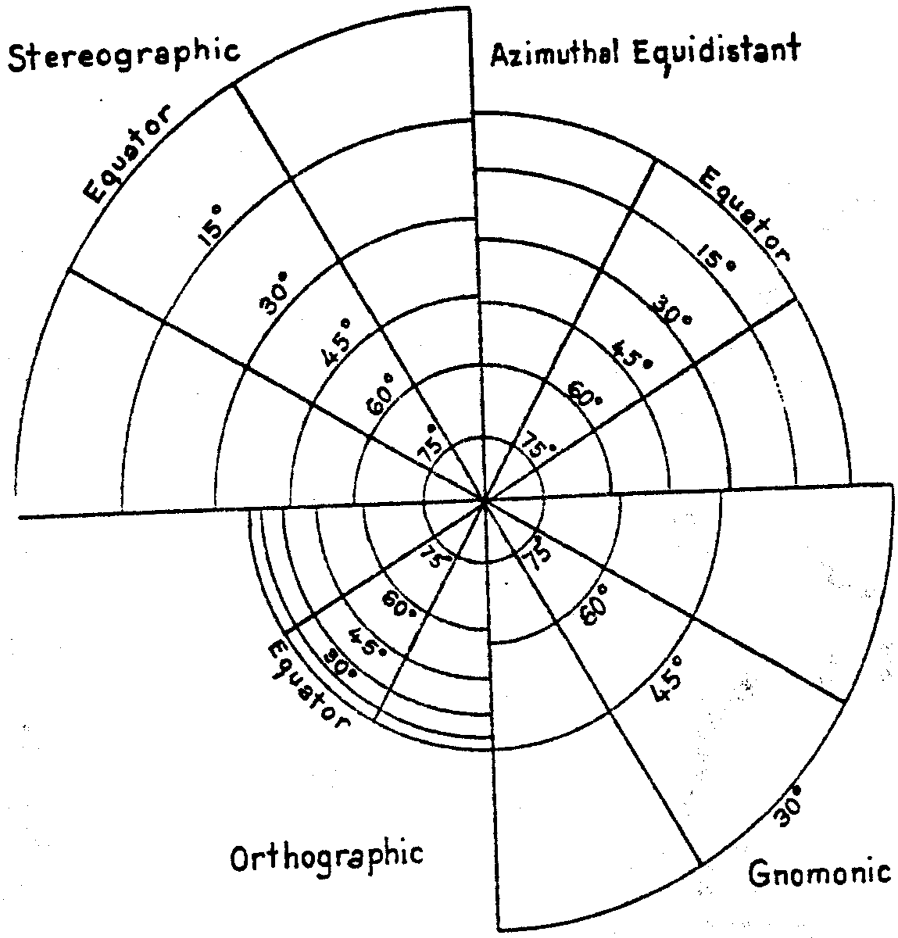
In the case of cylindrical projections in which the axis of the cylinder is parallel to the polar axis of the earth, distortion becomes excessive and the scale changes rapidly. Such projections cannot be carried to the poles. However, both the transverse and oblique Mercator projections are used.



An azimuthal equidistant map of the world with the point of tangency at latitude 40°N, longitude 100° W

Conic projections with their axes parallel to the earth's polar axis are limited in their usefulness for polar charts because parallels of latitude extending through a full 360° of longitude appear as arcs of circles rather than full circles. This is because a cone, when cur along an element and flattened, does not extend through a full 360° without stretching or resuming its former conical shape. The usefulness of such projections is also limited by the fact that the pole appears as an arc of a circle instead of a point. However, by using a parallel very near the pole as the higher standard parallel, a conic projection with two standard parallels can be made which requires little stretching to complete the circles of the parallels and eliminate that of the pole. Such a projection, called the **modified Lambert conformal** or **Ney's** projection, is useful for polar charts. It is particularly acceptable to those accustomed to using the ordinary Lambert conformal charts in lower latitudes.

Azimuthal projections are in their simplest form when tangent at a pole, since the meridians are straight lines intersecting at the pole, and parallels are concentric circles with their common center at the pole. Within a few degrees of latitude of the pole they all look essentially alike, but as the distance becomes greater, the spacing of the parallels becomes distinctive in each projection. In the polar azimuthal equidistant it is uniform; in the polar stereographic it increase with distance from the pole until the equator is shown at a distance from the pole equal to twice the length of the radius of the earth, or about 27% too much; in the polar gnomonic the increase is considerably greater, becoming infinity at the equator; in the polar orthographic it decreases with distance from the pole (the following figure). All of these but the last are used for polar charts.



Expansion of polar azimuthal projections.

Selection of a polar projection.—The principle considerations in the choice of a suitable projection for polar navigation are:

1. *Conformality.* It is desirable that angles be correctly represented so that plotting can be done directly on the chart, without annoying corrections.
2. *Great-circle representation.* Since great circles are more useful than rhumb lines in high latitude, it is desirable that great circles be represented by straight lines
3. *Scale variation.* Constant scale over an entire chart is desirable.
4. *Meridian representation.* Straight meridians are desirable for convenience and accuracy of plotting, and for grid navigation .

5. *Limits of utility.* Wide limits are desirable to reduce to a minimum the number of projections needed. The ideal would be a single projection for world coverage.

The projections commonly used for polar charts are thew modified Lambert conformal, gnomonic, stereographic, and azimuthal equidistant. Near the pole there is little to choose between them. Within the limits of practical navigation all are essentially conformal and on all a great circle is nearly a straight line.

As the distance from the pole increases, however, the distinctive features of each projection become a consideration. The modified Lambert conformal projection is virtually conformal over its entire extent, and the amount of its scale distortion is comparatively little if it is carried only to about 25° or 30° from the pole. Beyond this, the distortion increases rapidly. A great circle is very nearly a straight line anywhere on the chart. Distances and directions can be measured directly on the chart in the same manner as on a Lambert conformal chart. However, for highly accurate work this projection is not suitable, for it is not strictly conformal, and great circles are not exactly straight lines.

The polar gnomonic projection is the one polar projection on which great circles are exactly straight lines. A complete hemisphere cannot be represented upon a plane, because the radius of 90° from the center would become infinity.

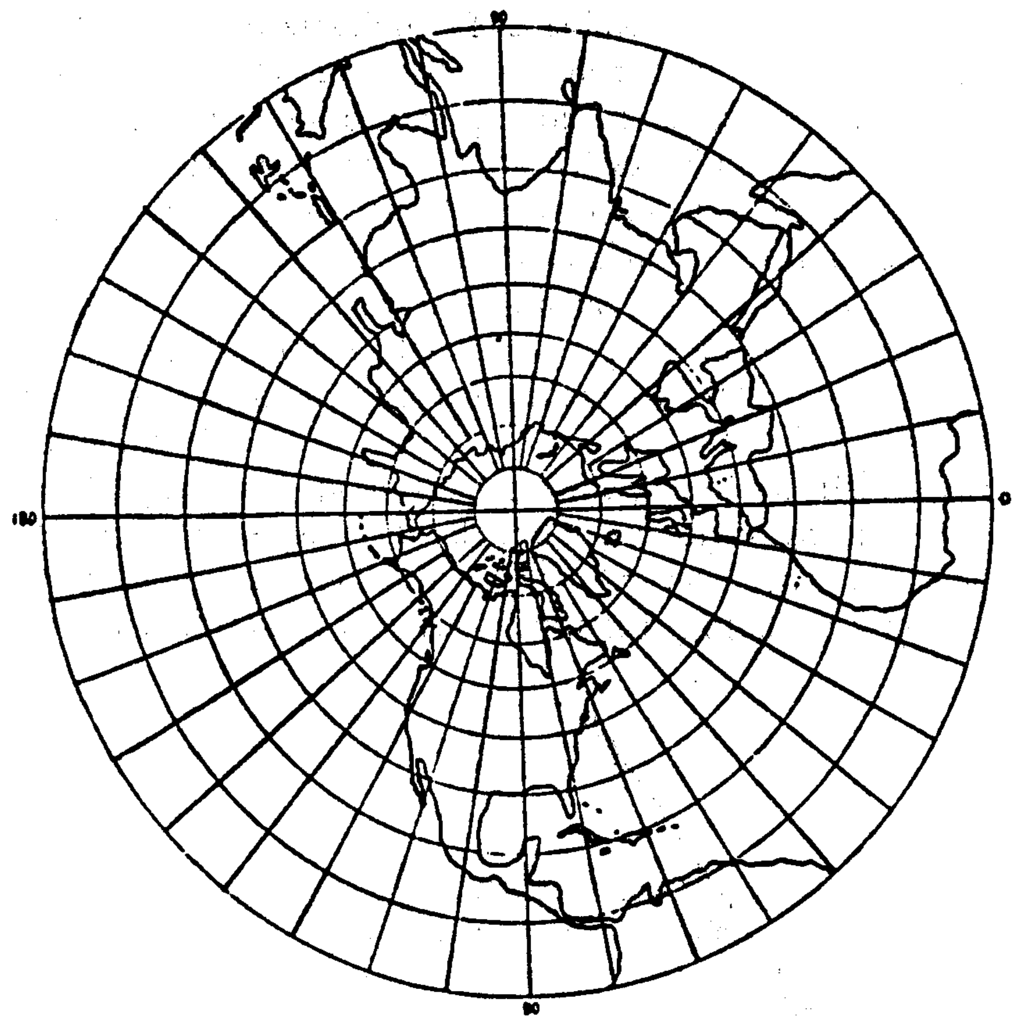
The polar stereogrpahic projection (the following figure) is conformal over its entire extent, and a great circle differs but little from a straight line. The scale distortion is not excessive for a considerable distance from the pole, but is greater than that of the modified Lambert conformal projection.

The polar azimuthal equidistant projection is useful for showing a large area such as a hemisphere, because there is no expansion along the meridians. However, the projection is not conformal, and distances cannot be measured accurately in any but a north-south direction. Great circles other than the meridians differ somewhat from straight lines. The equator is a circle centered at the pole.

The two projections most commonly used for charts for ordinary navigation near the poles are the modified Lambert conformal and the

polar stereographic. When a directional gyro is used as a directional reference, the track of the craft is approximately a great circle. A desirable chart is one on which a great circle is represented as a straight line with a constant scale and with angles correctly represented. These requirements are not met entirely by any single projection, but they are approximated by both the modified Lambert conformal and the polar stereographic. The scale is more nearly constant on the former, but the projection is not strictly conformal. The polar stereographic is conformal, and its maximum scale variation can be reduced by using a plane which intersects the earth at some parallel intermediate between the pole and the lowest parallel, so that that portion within this standard parallel is compresses, and that portion outside is expanded.

The selection of a suitable projection for use in polar regions, as in other areas, depends upon the requirements, which establish relative importance of the various features. For a relatively small area, any of several projections is suitable. For a large area, however, the choice is more critical. If grid directions are to be used, it is important that all units in related operations use charts on the same projection, with the same standard parallels, so that a single grid direction exists between any two points. Nuclear powered submarine operations under the polar icecap have increased the need for grid directions in marine navigation.



Polar stereographic projection.

Plotting Sheets

Definition and use. — A position plotting sheet is a plotting sheet designed primarily for plotting the dead reckoning and lines of position obtained from celestial observations or radio aids to navigation. It has the latitude and longitude graticule, and it may have one or more *compass roses* for measuring direction, but little or no additional information. The meridians are usually unlabeled by the publisher so the plotting sheet can be used for any longitude.

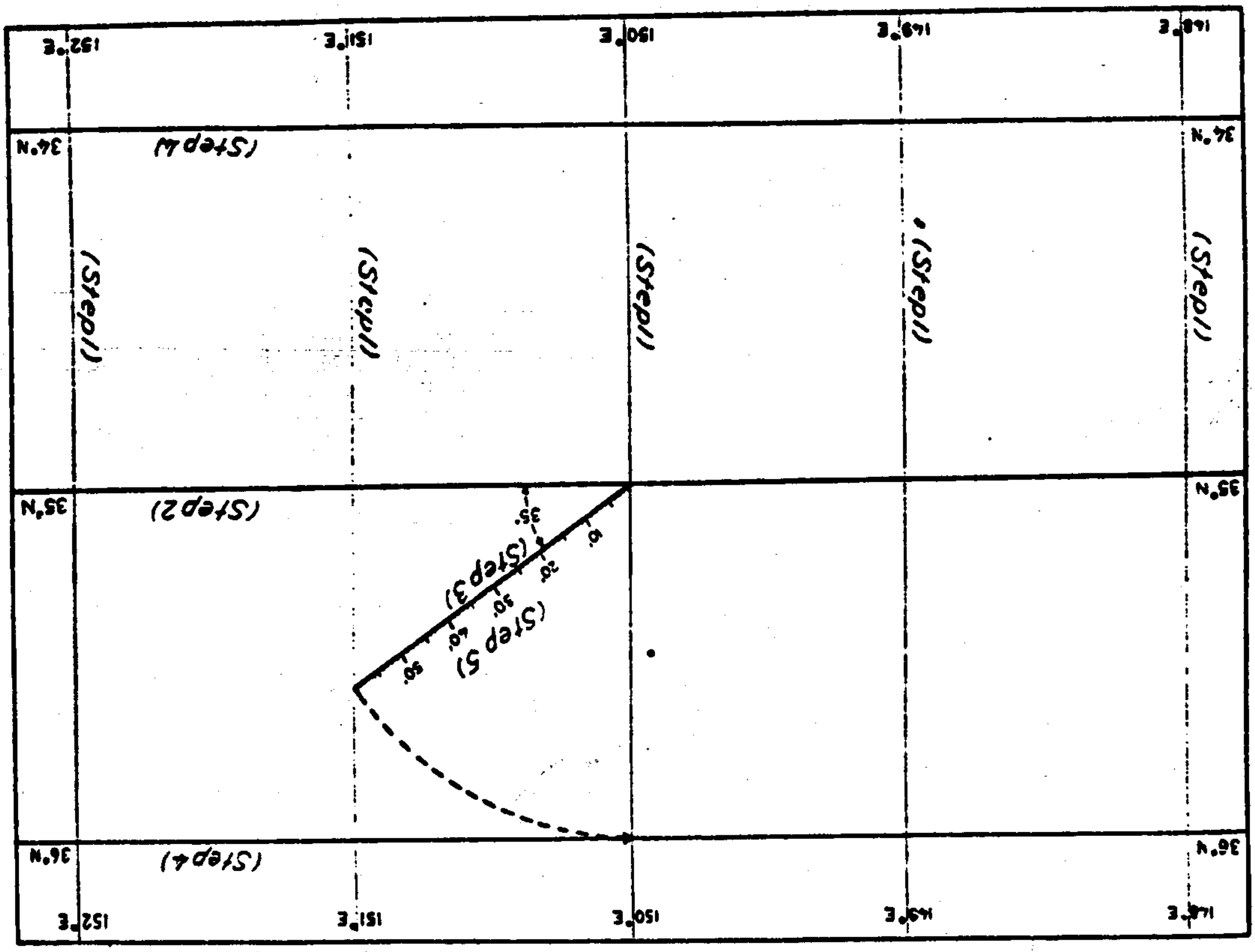
Plotting sheets are less expensive to produce than charts and are equally suitable or superior for some purposes. They are used primarily

when land, visual aids to navigation, and depth of water are not important.

Any projection can be used for constructing a plotting sheet, but that used for the navigator's charts is customarily employed also for his plotting sheets.

Small area plotting sheets.—A Mercator plotting sheet can be constructed by the method explained in article 307. For a relatively small area a good approximation can be more quickly constructed by the navigator by either of two alternative methods based upon a graphical solution of the secant of the latitude, which approximates the expansion.

First method (the following figure). *Step one*. Draw a series of equally spaced, vertical lines at any spacing desired. These are the meridians; label them at any desired interval, as 1', 2', 5', 10', 30', 1°, etc.



Small area plotting sheet with selected longitude scale.

Step two. Through the center of the sheet draw a horizontal line to represent the parallel of the mid-latitude of the area to be covered, and label it.

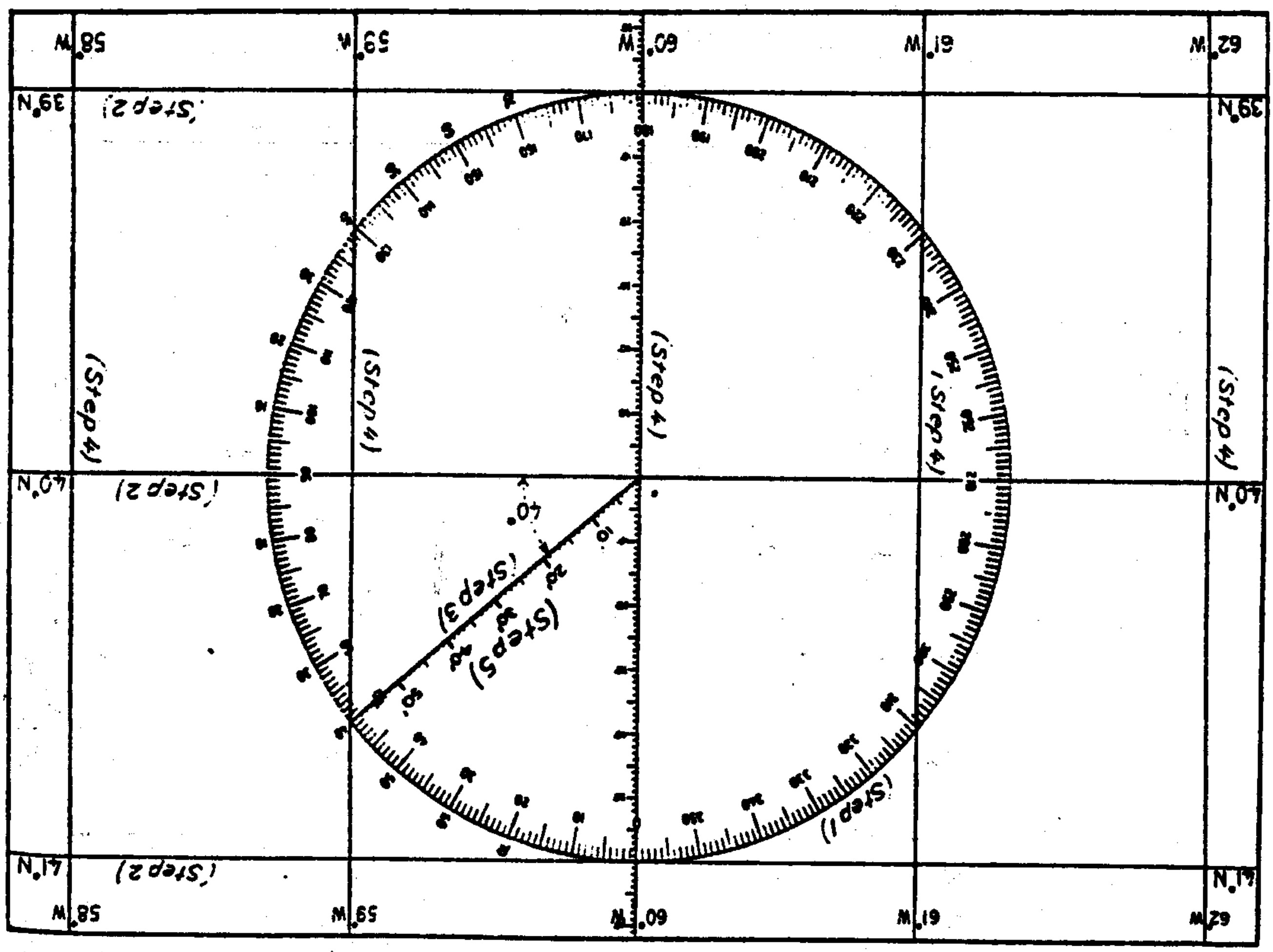
Step three. Through any convenient point, such as the intersection of the central meridian and the parallel of the mid-latitude, draw a line making an angle with the *horizontal* equal to the mid-latitude. In the following figure this angle is 35°.

Step four. Draw in and label additional parallels. The length of the oblique line between consecutive meridians is the perpendicular distance

between consecutive parallels, as shown by the broken arc. The number of minutes of arc between consecutive parallels thus drawn is the same as that between the meridians shown.

Step five. Graduate the oblique line into convenient units. If 1' is selected, this scale serves as both a latitude and mile scale. It can also be used as a longitude scale by measuring horizontally from a meridian instead of obliquely along the line.

Second method (the following figure). *Step one*. At the center of the sheet draw a circle with a radius equal to 1° (or any other convenient unit) of latitude at the desired scale. If a sheet with a compass rose is available, as in figure 324b, the compass rose can be used as the circle and will prove useful for measuring directions. It need not limit the scale of the chart, as an additional concentric circle can be drawn and desired graduations extended to it.



Small area plotting sheet with selected latitude scale

Step two. Draw horizontal lines through the center of the circle and tangent at the top and bottom. These are parallels of latitude; label them accordingly, at the selected interval (as every 1°, 30°, etc.).

Step three. Through the center of the circle draw a line making an angle with the *horizontal* equal to the mid-latitude. In figure 324b this angle is 40°.

Step four. Draw in and label the meridians. The first is a vertical line through the center of the circle. The second is a vertical line through the intersection of the oblique line and the circle. Additional meridians are drawn the same distance apart as the first two.

Step five. Graduate the oblique line into convenient units. If 1' is selected, this scale serves as a latitude and mile scale. It can also be used as a longitude scale by measuring horizontally from a meridians instead of obliquely along the line.

The same and result is produced by either method. The first method, starting with the selection of the longitude scale, is particularly useful when the longitude limits of the plotting sheet determine the scale. When the latitude coverage is more important, the second method may be preferable. If a standard size is desired, part of the sheet can be printed in advance, forming what is called a universal plotting sheet. This is done by the Defense Mapping Agency Hydrographic/Topographic Center. In either method a central compass rose might be printed. In the first method the meridians may be shown at the desired interval and the mid parallel may be printed and graduated in units of longitude. In using the sheet it is necessary only to label the meridians and draw the oblique line and from it determine the interval and draw in and label additional parallels. If the central meridian is graduated, the oblique line need not be. In the second method the parallels may be shown at the desired interval, and the central meridian may be printed and graduated in units of latitude. In using the sheet it is necessary only to label the parallels, draw the oblique line and from it determine the interval and draw in and label additional meridians. If the central meridian is graduated, as shown in the above figure, the oblique line need not be.

Both methods use a constant relationship of latitude to longitude over the entire sheet and both fail to allow for the ellipticity of the earth. For practical navigation these are not important considerations for a small area. If a larger area is to be shown or if more precise results are desired, the method of article 307 should be used.

Grids

Purpose and definition of grid.--No system has been devised for showing the surface of the earth *on a flat surface*, without distortion. Moreover, the appearance of any portion of the surface varies with the projection and, in many cases, with the location of the portion with respect to the point or line of tangency. For some purposes (particularly

military) it is desirable to be able to identify a location or area by rectangular coordinates, using numbers or letters, or a combination of numbers and letters, without the necessity of indicating the units used or assigning a name (north, south, east, or west), thus reducing the possibility of a mistake. This is accomplished by means of a grid. In its usual form this consists of two series of lines which are mutually perpendicular on the chart, with suitable designators.

Types of grids. ---A grid may use the rectangular graticule of the Mercator projection, or a set of arbitrary lines on a particular projection. The most widely used system of the first is called the World Geographic Referencing System (Georef). It is merely a method of designating latitude and longitude by a system of letters and numbers instead of by angular measure, and therefore is not strictly a grid, except on a Mercator projection. It is particularly useful for operations extending over a wide area. Examples of the second type of grid are the Universal Transverse Mercator (UTM) grid, the Universal Polar Stereographic (UPS) grid, and the Temporary Geographic Grid (TGG). Since these systems are used primarily by military forces, they are sometimes called military grids.

CHAPTER III
THE NAUTICAL CHART
General Information

Introduction.—A nautical chart is a conventional graphic representation, on a plane surface, of a navigable portion of the surface of the earth. It shows the depth of water by numerous soundings, and sometimes by soundings and depth contours, the shoreline of adjacent land, topographic features that may serve as landmarks, aids to navigation, dangers, and other information of interest to navigators. It is designed as a work sheet on which courses may be plotted, and positions ascertained. It assists the navigator in avoiding dangers and arriving safely at his destination. The nautical chart is one of the most essential and reliable aids available to the navigator.

Projections.—Nearly all nautical charts used for ordinary purposes of navigation are constructed on the Mercator projection. Large-scale harbor charts are sometimes constructed on the transverse Mercator projection. Charts for special purposes, such as great-circle sailing charts are usually on the gnomonic projection; polar charts are often on the polar stenographic projection. The principle projections, with their navigational uses, are discussed in chapter III.

Scale.—The *scale* of a chart is the ratio of a given distance on the chart to the actual distance which it represents on the earth. It may be expressed in various ways. The most common are:

A simple ratio or fraction known as the representative fraction. For example, 1:80.000 or

$$\frac{1}{80.000}$$

means that one unit (such as an inch) on the chart represents 80.000 of the same unit on the surface of the earth. This scale is sometimes called the **natural or fractional scale.**

A statement of that distance on the earth shown in one unit (usually an inch) on the chart, or vice versa. For example, "30miles to the inch" means that 1 inch on the chart represents 30 miles of the earth's surface. Similarly, "2 inches to a mile" indicates that 2 inches on the chart

represent 1 mile on the earth. This is sometimes called the numerical scale.

Graphic Scale. A line or bar may be drawn at a convenient place on the chart and subdivided into nautical miles, yards, etc. All charts vary somewhat in scale from point to point, and in some projections the scale is not the same in all directions about a single point. A single subdivided line or bar for use over an entire chart is shown only when the chart is of such scale and projection that the scale varies a negligible amount over the chart, usually one of about 1:75.000 or larger. Since 1 minute of latitude is very nearly equal to 1 nautical mile, the latitude scale serves as an approximate graphical scale. On most nautical charts the east and west borders are subdivided to facilitate distance measurements.

On a Mercator chart the scale varies with the latitude. This is noticeable on a chart covering a relatively large distance in a north-south direction. On such a chart the scale at the latitude in question should be used for measuring distances.

Of the various methods of indicating scale, the graphical method is normally available in some form on the chart. In addition, the scale is customarily stated on charts on which the scale does not change appreciably over the chart.

The ways of expressing the scale of a chart are readily interchangeable. For instance, in a nautical mile there are about 6.076.11549 feet or 6.076.11549×12=72.913.39 inches. If the natural scale of a chart is 1:80.000, one inch of the chart represents 80.000 inches of the earth, or a little more than a mile. To find the exact amount, divide the scale by the number of inches in a mile, or

$$\frac{80.000}{72,913.39} = 1.097$$

Thus, a scale of 1:80,000 is the same as a scale of 1.097 (or approximately 1.1) miles to an inch. Stated another way, there are:

$$\frac{72,913.39}{80,000} = 0.911$$

CHAPTER III

THE NAUTICAL CHART

(approximately 0.9) inch to a mile. Similarly, if the scale is 60 nautical miles to an inch. The representative fraction is 1:(60×72,913.39)=1:4,374,803. Table 37 provides the scale equivalents.

A chart covering a relatively large area is called a *small-scale* chart and one covering a relatively small area is called a *large-scale* chart. Since the terms are relative, there is no sharp division between the two. Thus, a chart of scale 1:100,000 is large scale when compared with a chart of 1:1,000,000 but small scale when compared with one of 1:25,000.

Chart classification by scale.---Charts are constructed on many different scales, ranging from about 1:2,500 to 1:14,000,000 (and even smaller for some world charts). Small-scale charts covering large areas are used for planning and for offshore navigation. Charts of larger scale, covering smaller areas, should be used as the vessel approaches pilot waters. Several methods of classifying charts according to scale are in use in various nations. The following classifications of nautical charts are those used by the National Ocean Service.

Sailing charts are the smallest scale charts used for planning, fixing position at sea, and for plotting the dead reckoning while proceeding on a long voyage. The scale is generally smaller than 1:600,000. The shoreline and topography are generalized and only offshore soundings, the principle navigational lights, outer buoys. and landmarks visible at considerable distances are shown.

General charts are intended for coastwise navigation outside of outlying reefs and shoals. The scales range from about 1:150,000 to 1:600,000.

Coast charts are intended for inshore coastwise navigation where the course may lie inside outlying reefs and shoals, for entering or leaving bays and harbors of considerable width, and for navigating large inland waterways. The scales range from about 1:50,000 to 1:150,000.

Harbor charts are intended for navigation and anchorage in harbors and small waterways. The scale is generally larger than 1:50,000.

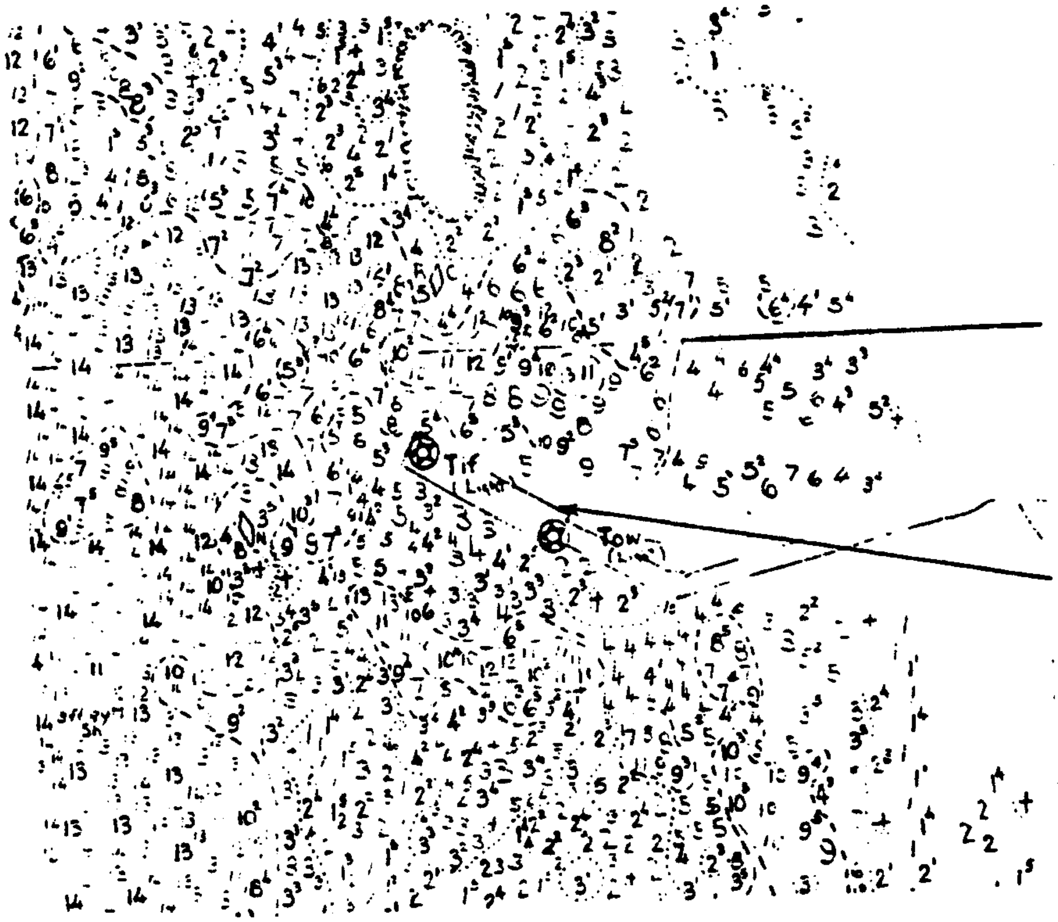
In the classification system used by the Defense Mapping Agency Hydrographic/Topographic Center, the sailing charts are incorporated in the general charts classification (smaller than about 1:150,000); those

coast charts especially useful for approaching more confined waters (bays, harbors) are classified as approach charts.

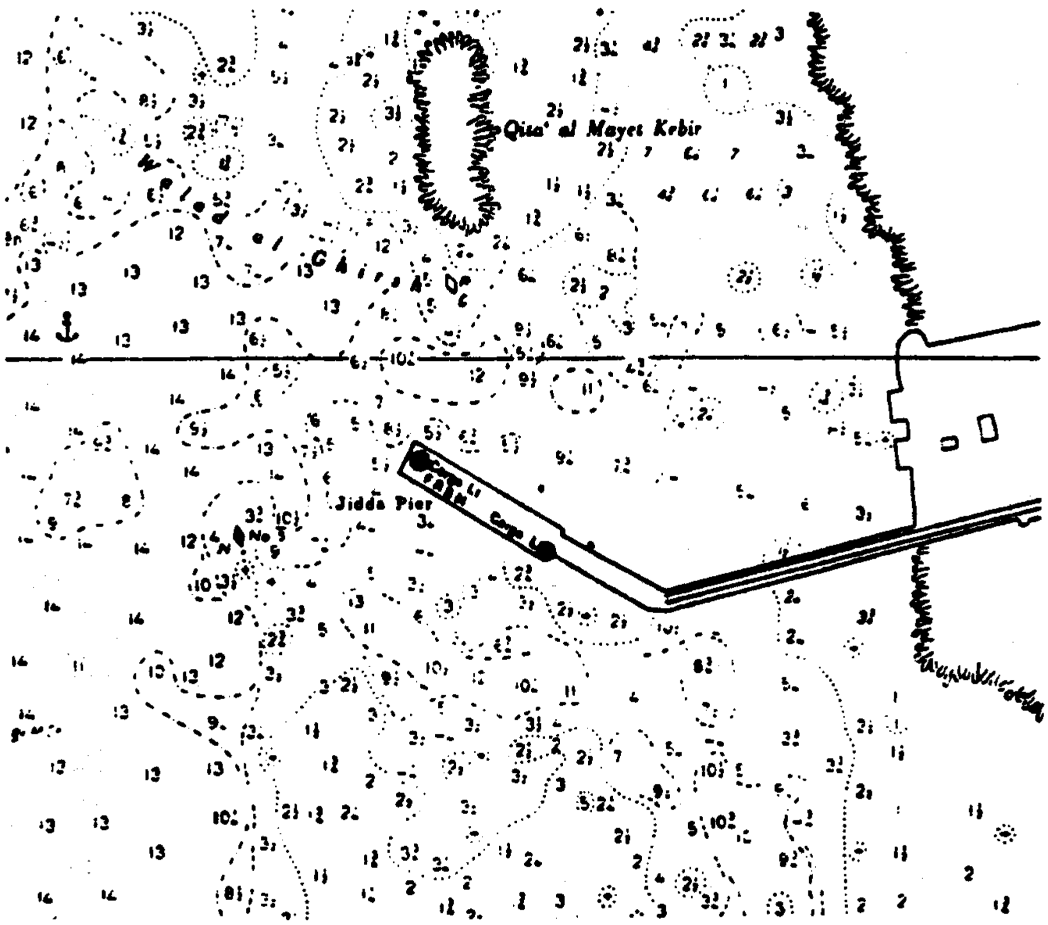
Accuracy.—The accuracy of a chart depends upon:

1. *Thoroughness and up-to-dateness of the survey and other navigational information.* Some estimate of the accuracy of the survey can be formed by an examination of the source noted given in the title of the chart. If the chart is based upon very old surveys, it should be used with caution. Many of the earlier surveys were made under conditions that were not conductive to great accuracy. It is safest to question every chart based upon surveys of doubtful accuracy.

The number of soundings and their spacing is some indication of the completeness of the survey. Only a small fraction of the soundings taken in a thorough survey are shown on the chart, but sparse or unevenly distributed soundings indicate that the survey was probably not made in detail. Large or irregular blank areas, or absence of depth contours (commonly called depth curves), generally indicate lack of soundings in the area. If the water surrounding such a blank area is deep, there is generally considerable depth in the blank; conversely, shallow water surrounding such an area indicates the strong possibility of shoal water. If neighboring areas abound in rocks or are particularly uneven, the blank area should be regarded with additional suspicion. However, it should be kept in mind that relatively few soundings are shown when there is a large number of depth contours or where the bottom is flat or gently and evenly sloping. Additional soundings are shown when they are helpful in indicating the uneven character of a rough bottom (the following figures).



Part of a boat sheet, showing the soundings obtained in a survey



Part of a nautical chart from the boat sheet of figure 505a. Compare the number of soundings in the two figures.

Even a detailed survey may fail to locate every rock or pinnacle, and in waters where their existence is suspected, the best methods fro determining their presence are wire drag surveys. Areas that have been dragged may be indicated on the chart and a note added to show the effective depth at which the drag was operated.

Changes in the contour of the bottom are relatively rapid in areas where there are strong currents or heavy surf, particularly when the bottom is composed principally of soft mud or sand. The entrances to bar harbors are especially to be regarded with suspicion. Similarly, there is

sometimes a strong tendency for dredged channels to shoal, especially if they are surrounded by sand or mud, and cross currents exist. Notes are sometimes shown on the chart when the bottom contours are known to change rapidly. However, the absence of such a note should not be regarded as evidence that rapid change does not occur.

Changes in aids to navigation, structures, etc., are more easily determined, and charts are generally corrected in the this regard to the date of printing. However, there is always the possibility of a change having occurred since the chart was printed. All issues of *Notice to Mariners* printed after that data (art. 506) should be checked to insure accuracy in this respect.

2. Suitability of the scale for the design and intended navigational use. The same detail cannot be shown on a small-scale as on one of a larger scale. On small-scale charts detailed information, including minor aids to navigation, is omitted or generalized in the areas covered by larger scale charts. Therefore, it is good practice to use the largest scale chart available when in the vicinity of shoals or other dangers.

3. Presentation and adequacy of data. The amount and kind of detail to be shown, and the method of presentation, are continually under study by charting agencies. Development of a new navigational aid may render many previous charts inadequate. An example is radar. Many of the charts produced before radar became available lack the detail needed for reliable identification of targets.

Part of the responsibility for the continuing accuracy of charts lies with the user. If charts are to remain reliable, they must be corrected as indicated by the *Notice to Mariners*. In addition, the user's reports of errors and changes and his suggestions often are useful to the publishing agencies in correcting and improving their charts. Navigators and maritime activities have contributed much to the reliability and usefulness of the modern nautical chart. If a chart becomes wet, the expansion and subsequent shrinkage when the chart dries are likely to cause distortion.

Dates on charts.—The system of dates now used on chrts published by the Defense Mapping Agency Hydrographic /Topographic Center and National Ocean Services is as follows:

First edition. The original date of issue of a new chart is shown at the top center margin, thus:

1st Ed., Sept. 1970

New edition. A new edition is made when, at the time of printing, the corrections are too numerous or too extensive to be reported in *Notice to Mariners*, making previous printings obsolete. The date of the first edition is retained at the top margin. At the lower left-hand corner it is replaced by the number and date of the new edition. The latter date is the same as that of the latest *Notice to Mariners* to which the chart has been corrected, thus:

5th Ed., July 8, 1978

Revised print. A revised print published by the National Ocean Service may contain corrections which have been published in Notice to Mariners but does not supersede a current edition. The date of the revision is shown to the right of the edition date, thus:

5th Ed., July 8, 1978; Revised 4/16/83

Reprint. A reprint is initiated by a low stock situation and is a reprint of the chart with a limited number of corrections from *Notice to Mariners*. The magnetic variation data on a reprint published by the Defense Mapping Agency Hydrographic/Topographic Center is updated to the latest epoch at the time of printing.

Chart Reading

Chart symbols.—Much of the information contained on charts is shown by conventional symbols which make no attempt at accuracy in scale or detail, but are shown at the correct location and make possible the showing of a large amount of information without congestion or confusion. The standard symbols and abbreviations which have been approved for use on regular nautieal charts published by the United States of America are shown jn Chart No.1, *Nautical Chart Symbols and Abbreviations*. A knowledge of the meanings of these symbols is essential

to a full understanding of charts. Fictitious sample charts (the following figures) show some of these symbols.

Most of the symbols and abbreviations shown in chart No. 1 are in agreement with those recommended by the International Hydrographic Organization (**IHO**). Symbol And abbreviation status is indicated by alphanumeric style differences in the first column of Chart No. 1. The status is explained in the general remarks section of Chart No. 1.

The symbols and abbreviations on any given chart differ somewhat from those shown in Chart No. 1 because of a change in the standards since printing of the chart or because the chart was published by an agency having a different set of standards.

Lettering.—Certain standards regarding lettering have been adopted, except on charts made from reproducibles furnished by foreign nations.

Vertical type is used for features which are dry at high water and not affected by movement of the water, except for heights above water.

Slanting type is used for water, underwater, and floating features, except soundings.

The type of lettering used be the only means of determining whether a feature may be visible at high tide. For instance, a rock might bear the title "........ Rock" whether or not it extends above the surface. If the name is given in vertical letters, the rock constitutes a small islet; if in slanting type, the rock constitutes a reef.

The shoreline shown on nautical charts represents the line of contact between the land and a selected water elevation. In areas affected by tidal fluctuations, this line of contact is usually the means hig-water line. In confined coastal waters of diminished tidal influence, a mean water level line may be used. The shoreline of interior waters (rivers, lakes) is usually a line representing a specified elevation above a selected datum. A shoreline is symbolized by a heavy line. A broken line indicates that the charted position is approximate only. The nature of the shore may be indicated, as shown by the symbols in part A of Chart No. 1.

Where the low-water line differs considerably from the high-water line, the low-water line may be indicated by dots in the case of mud, sand, gravel, or stones, with the kind of material indicated, and by a characteristic symbol in the case of rock or coral. The area alternately

covered and uncovered may be shown by a tint which is usually a combination of the land tint and a water tint as shown in the following figures.

The apparent shoreline is used on charts to show the outer of marine vegetation where that limit would reasonably appear as the shoreline to the mariner, or where it prevents the shoreline from being clearly defined. The apparent shoreline is symbolized by a light line. The inner edge is marked by a broken line when no other symbol (such as a cliff, levee, etc.) furnishes such a limit. The area between inner and outer limits may be given the combined land-water tint or the land tint.

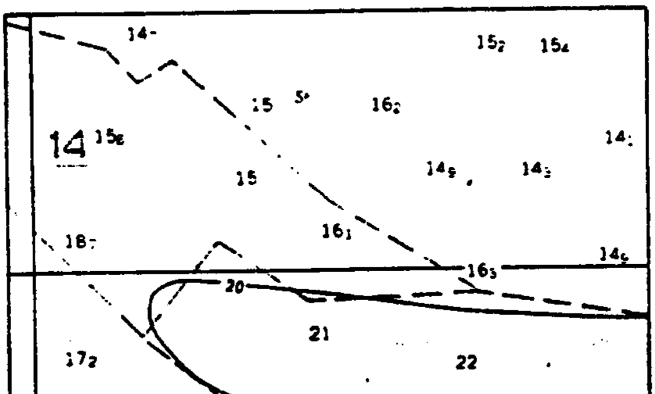
Water areas.—Soundings or depths of water are shown in several ways. Individual soundings are shown by numbers. These do not follow the general rule for lettering. They may be either vertical or slanting, or both may be used on the same chart to distinguish between the data based upon different surveys, different datums, smaller scale charts, or furnished by different authorities.

The unit of measurement used for soundings on each chart is shown in large block letters at the top and bottom of the chart. When the unit of measurement is meters or meters and decimeters, **SOUNDINGS IN METERS** is shown. When soundings in fathoms or fathoms and fractions are used, **SOUNDINGS IN FATHOMS** is shown, and when the soundings are in fathoms and feet, **SOUNDINGS IN FATHOMS AND FEET** is shown.

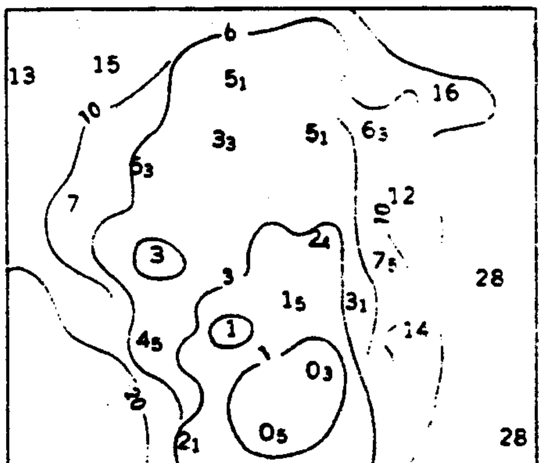
A depth conversion scale is placed outside the neatline on the chart for use in converting charted to feet, meters, or fathoms.

"No bottom" soundings are indicated by a number with a line over the top and a dot over the line, thus:45 . This indicates that the spot was sounded to the depth indicated without reaching the bottom. Areas which have been wire dragged (the following figure) are shown by a broken limiting line, and the clear effective depth is indicated, with a characteristic symbol under the numbers. On charts of the Defense Mapping Agency Hydrographic/Topographic Center, a purple tint is shown within the limits of the swept area unless such tinting would result in excessive use of purple, in which case a green tint is shown within the limits of the swept area.

The soundings are supplemented by a series of *depth contours* (the following figure) connecting points of equal depth. These line present a graphic indication of the configuration of the bottom. The types of lines used for various depths are shown in part R of Chart No. 1. On some charts depth contours are shown in solid lines, the depth represented by each being shown by numbers placed in breaks in the lines, as with land contours. Solid line depth contours are derived from intensively developed hydrographic survey. *A broken or indefinite contour is substituted for a solid depth contour whenever the reliability of the contour is questionable*. Depth contours are labeled with numerals in the unit of measurement of the soundings. This type chart, presenting a more detailed indication of the bottom configuration with fewer numerical soundings, is particularly useful to the vessel equipped with an echo sounder permitting continuous determination of a profile of the bottom. Such a chart, to be reliable, can be made only for areas which have been surveyed in great detail.



Swept area



Depth contours.

Areas which uncover at low tide are tinted as indicated in article 509. Those areas out to a given depth are given a blue tint, and occasionally a

lighter blue is carried to some greater depth. On older charts the one-, two-, and three- fathom curves have stippled edges. Charts designed to give maximum emphasis to the configuration of the bottom show depths, beyond the 100-fathom curve, over the entire chart by depth contours similar to the contours shown on land areas to indicate graduations in height. These are called *bottom contour or bathymetric* charts.

The side limits of dredged channels are indicated by broken lines. The project depth and the date of dredging, if known, are shown by a statement in or along the channel. The possibility of silting should be considered. Local authorities should be consulted for the *controlling depth*.

The chart scale is generally too small to permit all soundings to be shown. In the selection of soundings to be shown, *least* depths are generally chosen first and a sounding pattern worked out to provide safety, a practical presentation of the bottom configuration, and a neat appearance. Depths greater than those indicated may be found close to charted depths, but steep changes in depth are given every consideration in sounding selection. Also, the state of the tide affects the depth at any given moment. An isolated shoal sounding should be approached with caution, or avoided, unless it is known that the area has been wire dragged, for there is always the possibility that a depth less than the least shown may have escaped detection. Also, the shoal area near a coast little frequented by vessels is sometimes not surveyed with the same thoroughness as other areas. Such areas and those where rocks, coral, etc., are known to exit should be entered with caution, or avoided.

The substance forming the bottom is shown by abbreviations, as listed in part S of Chart No. 1. The meaning of some of the less-well-known terms is given below:

Ooze is a soft, slimy, organic sediment composed principally of shells or other hard parts of minute organisms.

Marl is a crumbling, earthy deposit, particularly one of clay mixed with sand, lime, decomposed shells, etc. A layer of marel may become quite compact.

Shingle consists of small, rounded, waterworn stones. It is similar to gravel but with the average size of stone generally larger.

Schist is crystalline rock of a finely laminated nature.

Madrepore is a stony coral which often forms an important building material for reefs.

Lava is rock in the fluid state, or such material after it has solidified. It is formed at very high temperature and issues from the earth through volcanoes.

Pumice is cooled volcanic glass with a great number of minute cavities caused by the expulsion of water vapor at high temperature, resulting in a very light material.

Tufa is a porous rocky deposit sometimes formed in streams and in the ocean near the mouths of rivers.

Scoria (plural scoriae) is rough, cinder like lava.

Sea tangle is any of several species of seaweed, especially those of large size.

Spicules are the small skeletons of various marine animals such as sponges.

Foraminifera (plural) are small marine animals with hard shells of from one to many chambers.

Globigerina is a very small animal of the formainifera order, with a chambered shell, or the shell of such an animal. In large areas of the ocean the calcareous shells of these animals are very numerous, being the principal constituent of a soft mud or globigerina ooze, forming part of the ocean bed.

Diatom is a microscopic animal with external skeletons of silica, often found in both fresh and salt water. Part of the ocean bed is composed of a sedimentary ooze consisting principally of large collections of the skeletal remains of diatoms.

Radiolaria (plural) are minute sea animals with a siliceous outer shell. The skeletons of these animals are very numerous, especially in the tropics.

Pteropod is a small marine animal with or without a shell and having two thin, wing like feet. These animals are often so numerous they cover the surface of the sea for miles. In some areas their shells cover the bottom.

Polyzoa (plural) are very small marine animals which reproduce by budding, many generations often being permanently connected by branch like structures.

Cirripeda (plural) are barnacles and certain other parastic marine animals.

Fucus is a coarse growing attached to rocks.

Matte is dense, twisted growth of a sea plant such as grass.

"Calcareous" is an adjective meaning "containing or composed of calcium or one of its compounds".

Chart sounding datum.—*Depths.* All depths indicated on charts are reckoned from some selected level of the water, called the *chart sounding datum*. The various chart datum are explained in chapter **XXXI**. On charts made from surveys conducted by the United States the chart datum is selected with regard to the tides of the region, so that depths might be shown in their least favorable aspect. On charts based upon those of other nations the datum is that of the original authority. When it is known, the datum used is stated on the chart. In some cases where the chart is based upon old surveys, particularly in areas where the range of tide is not great, the actual chart datum may not be known.

For National Ocean Services charts of the Atlantic and gulf coasts of the united States and Puerto Rico the chart datum is *mean low water*. For charts of the Pacific coast of the United States, including Alaska, it is *mean lower low water*. Most Defense Mapping Agency Hydrographic/Topographic Center charts are based upon *mean low water, mean lower low water, or mean low water springs*. The chart datum for charts published by other countries varies greatly, but is usually lower than mean low water. On charts of the Baltic Sea, Black Sea, the Great Lakes, and other areas where tidal effects are small or without significance, the datum is an arbitrary height approximating the mean water level.

The chart datum of the largest-scale charts of an area is generally the same as the reference level from which height of tide is tabulated in the tide tables.

The height of a chart datum is usually only an approximation od the actual mean value specified , for determination of the actual mean height

usually requires a longer series of tidal observations than is available to the cartographer, and the height changes somewhat over a period of time.

Since the chart datum is generally a computed mean or average height at some state of the tide, the depth of water at any particular moment may be less than shown on the chart. For example, if the chart datum is *mean lower low water*, the depth of water at *lower low water* will be less than the charted depth about as often as it is greater. A lower depth is indicated in the tide tables by a minus sign (--).

Heights. The shoreline shown on charts is the high-water line, generally the level of mean high water. The heights of lights, rocks, islets, etc., are generally reckoned from this level. However, heights of islands, especially those at some distance from the coast, are often taken from sources other than hydrographic surveys, and may be reckoned from some other level, often mean sea level. The plane of reference for topographic detail is frequently not stated on the chart.

Since heights are usually reckoned from high water and depth from some form of low water, the reference levels are seldom the same. This is generally of little practical significance, but it might be of interest under some conditions, particularly where the range of tide is large.

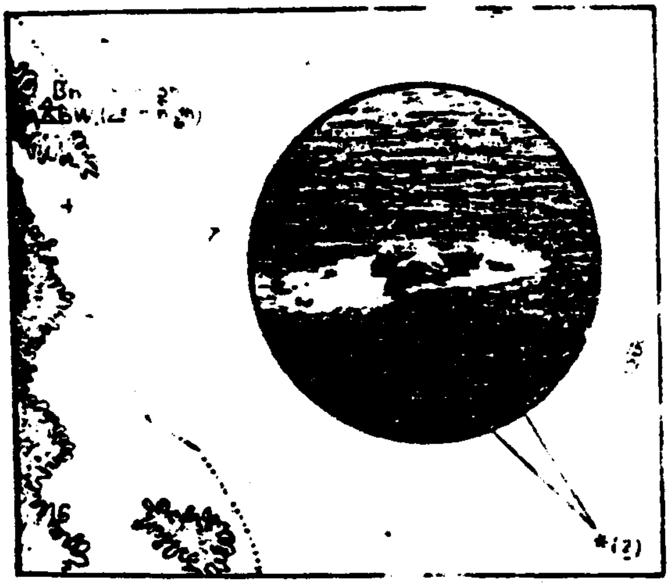
Dangers are shown by appropriate symbols, as indicated in part O of Chart No.1.

A rock that uncovers at mean high water may be shown as an islet. If an isolated, of flying rock is known to uncover at the chart datum but to be covered at high water, the appropriate symbol is shown and the height above the chart datum, if known, is usually given, either by statement such as "*Uncov 2 ft*" or by the figure indicating the number of feet above the chart datum underlined and usually enclosed in parentheses, thus: (2). This is illustrated in figure 512a. A rock which does not uncover is shown by the appropriate symbol. If it is considered a danger to surface vessels, the symbol is enclosed by a dotted curve for emphasis.

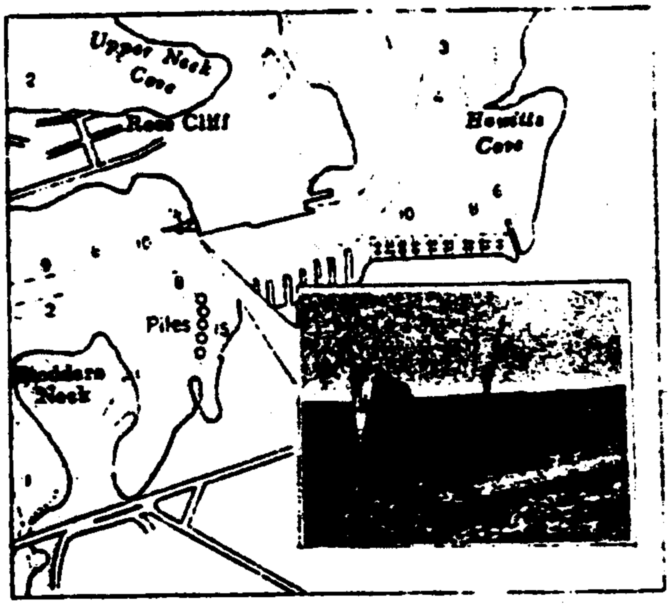
A distinctive symbol is used to show a detected coral reef which uncovers at the chart datum. For a coral or rocky reef which is submerged at chart datum, the sunken rock symbol or an appropriate statement is used, enclosed by a dotted or broken line if the limits have been determined.

Several different symbols are used for wrecks, depending upon the nature of the wreck or scale of the chart. The usual symbol for a visible wreck is shown in the following figure. A sunken wreck with less than 11 fathoms of water over it is considered dangerous and its symbol is surrounded by a dotted curve The safe clearance depth found over a wreck is indicated by a standard sounding number placed at the wreck, (the following figure). If this depth is determined by a wire drag, the sounding is underscored by the wire drag symbol . An unsurveyed wreck over which the exact depth is unknown, but is considered to have a safe clearance to the depth shown is depicted as shown in Page 122.

Tide rips, eddies, and kelp are shown by symbol or lettering.



Arock awash.



A visible wreck.

Piles, dolphins (clusters of piles), snags, stumps, etc., are shown by small circles and a label identifying the type of obstruction. If such dangers are submerged, the letters "Subm" precede the label.

Fish stakes and traps are shown when known to be permanent or hazardous to navigation.

The importance of knowing the chart symbols for dangers to navigation cannot be emphasized strongly enough. Most dangers are emphasized with a blue tint and dotted line surrounding the danger. Some of the danger symbols are shown in the following figure.

Aids to navigation are shown by symbol, as given in Chart No. 1, usually supplemented by abbreviations and sometimes by additional descriptive text. In order to render the symbols conspicuous it is necessary to show them in greatly exaggerated size relative to the scale of the chart. It is therefore important that the navigator know which part of the symbol represents the actual position of the aid. For floating aids (lightships and buoys), the position part of the symbol marks the approximate location of the anchor or sinker, the aid swinging in an orbit around this approximate position.

The principal charted aids to navigation are lighthouses, other lights on fixed structures, beacons, lightships, radiobeacons, and buoys. The number of aids shown and the amount of information concerning them varies with the scale of the chart. Unless otherwise indicated, lights which do not alternate in color are white, and alternating lights are red and white. Light lists give complete navigational information concerning them.

Lighthouses and *other lights on fixed structures* are shown as black dots surrounded by nautical purple disks or as black dots with purple flare symbols. The center of the black dot is the position of the light.

	Sunken wreck dangerous to surface navigation (less than 11 fathoms over wreck).
	Sunken rock dangerous to navigation.
3 Wk	Wreck over which depth is known.
21 Wk	Wreck with depth cleared by wire drag.
8 Wk	Unsurveyed wreck over which the exact depth is unknown, but is considered to have a safe clearance to the depth shown.
5 Rk	Shoal sounding on isolated rock.
Co	Coral reef covered at sounding datum.
Foul	Foul ground, Foul bottom.
*(2) or (2)	Rock which covers and uncovers with height above chart sounding datum.
Subm Piles	Submerged pilings.
3 Rep (1974)	Depth reported in 1974.
Reef	Reef of unknown extent.
4 Obstr	Obstruction
Platform (lighted) HORN	Offshore platform (unnamed)
3	Drying (or uncovering) heights, above chart sounding datum.

Danger symbols.

On large-scale charts the characteristics of lights are shown in the following order:

Characteristic	*Example*	*Meaning*
1. Character	Fl (2)	group flashing (2 flashes)
2. Color	R	red
3. Period	10s	10 seconds
4. Height	160 ft	160 feet
5. Range	19 M	19 nautical miles (See article 1307)
6. Number	"6"	Light number 6

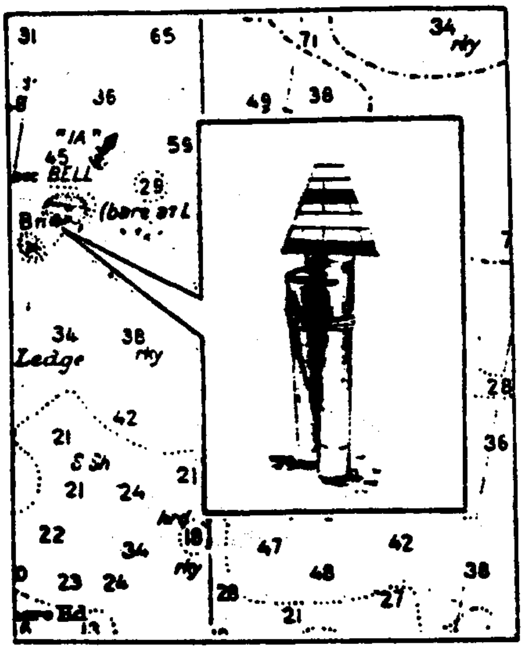
The legend for this light would appear on the chart:

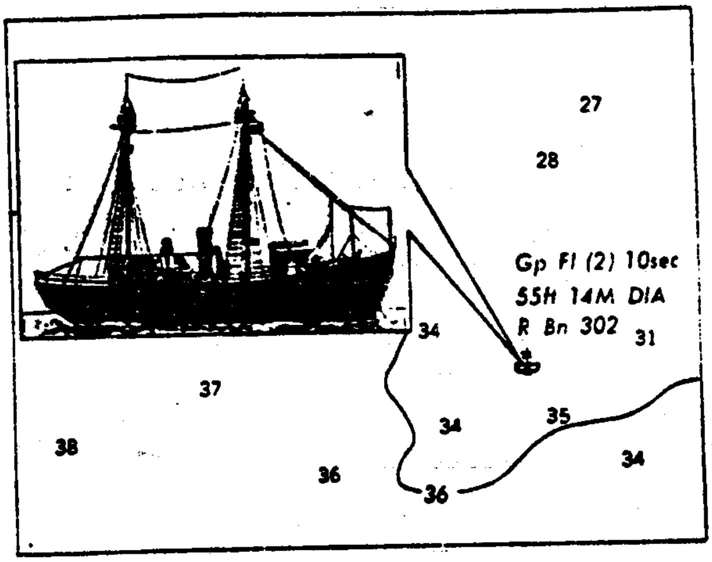
Fl (2) R 10s 160 ft 19 M "6"

On older charts this form is varied slightly. As the chart scale becomes smaller the six items listed above are omitted in the following order: first, height; second, period (seconds); third, number (of flashes, etc.) in group; fourth, light number; fifth, visibility. Name of unnumbered lights are shown when space permits.

Daybeacons (unlighted beacons) are shown as depicted in Chart No. 1. When daybeacons are shown by small triangles, the center of the triangle marks the position of the aid. Except on Intracoastal Waterway charts and charts of state waterways the abbreviation Bn is shown beside the symbol, with the appropriate abbreviation for color if known. For black beacons the triangle is solid black and there is no color abbreviation. All beacon abbreviations are in vertical lettering, as appropriate for fixed aids (the following figure 1).

Lightships are shown by ship symbol, the center of the small circle at the base of the symbol indicating the approximate position of the lightship's anchor. The circle is overprinted by a small purple disk as shown in (the following figure 2) or a purple flare emanating from the top of the symbol. As a floating aid, the light characteristics and the name of the lightship are given in leaning letters.





A daybeacon **A lightship with a radiobeacon.**

Radiobeacons are indicated on the chart by a small purple circle, as shown in the second figure above, accompanied by the appropriate abbreviation to indicate whether an ordinary radiobeacon (R Bn) or a radar beacon (Racon). The same symbol is used for a radio direction finder station with the abbreviation "RDF" and a coast radar station with the abbreviation Ra. Other radio stations are indicated by a small black circle with a dot in the center, or a smaller circle without a dot, and the appropriate abbreviation. In every case the center of the circle marks the position of the aid.

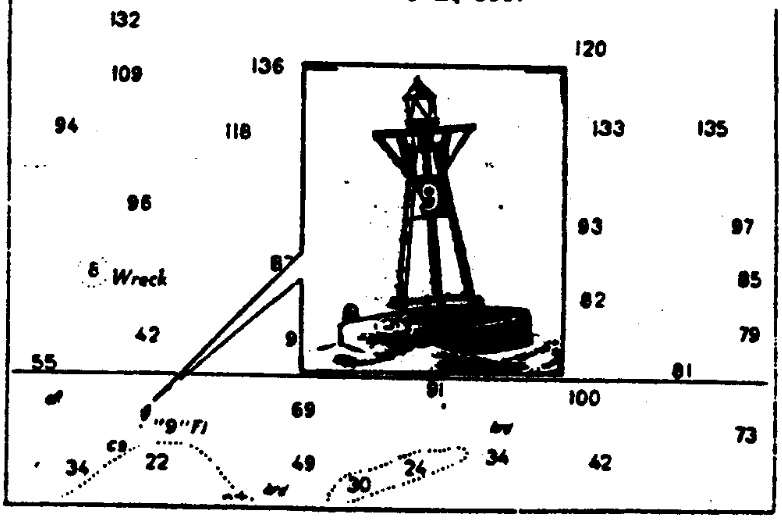
Buoys, except mooring buoys, are usually shown by a dimand-shaped symbol and a small dot or small circle in conjunction with one of it points (at one of its acute angles). The dot or small circle indicates the approximate position of the buoy's sinker. A mooring buoy is shown by a distinctive symbol as indicated in part L of Chart No. 1. The small circle interrupting the symbol's base line indicates the approximate position of the sinker.

A black buoy is shown by a solid black diamond symbol, without abbreviation. For all other buoys, color is indicated by an abbreviation, or in full by a note on the chart. In addition, the diamond-shaped symbols of red buoys often are colored purple. A buoy symbol with a line connecting the side points (shorter axis), half of the symbol being purple or open and the other half black, indicates horizontal bands. A line connecting the upper and lower points (longer axis) represents vertical stripes. Two lines connecting the opposite sides of the symbol indicate a checkered buoy.

There is no significance to the angle at which the diamond-shape appears on the chart. The symbol is placed so as to avoid interference with other features of the chart.

Lighted buoys are indicated by a purple flare emanating from the buoy symbol or by a small purple disk centered on the dot or small circle indicating the approximate position of the buoy's sinkers, as shown in the following figure.

Abbreviations for light characteristics, type and color of buoy, number of the buoy, and any other pertinent information given near the symbol are in slanting letters. The letters C, N, or S, indicates a can, nun, or spar, respectively. The words "bell", "gong", and "whistle", are shown as ***BELL***, ***GONG***, and ***WHIS***, respectively. The number or letter designation of the buoy is given in quotation marks on National Ocean Service charts. On other charts they may be given without quotation marks or punctuation, thus: No 1. No 2, etc.



A lighted buoy.

Station buoys are not shown on small-scale charts, but are given on some large-scale charts.

Aeronautical lights included in the light lists are shown by the lighthouse symbol, accompanied by the abbreviation "AERO". The completeness to which the characteristics are shown depends principally upon the effective range of other navigational lights in the vicinity, and the usefulness of the light for marine navigation.

Ranges are indicated by a broken or solid line. The solid line, which indicates that part of the range intended for navigation, may be broken at irregular intervals to avoid being drawn through soundings. The part of the range line drawn only to guide the eye to the objects to be kept in range is broken at regular intervals. If the direction is given, it is expressed in degrees clockwise from true north.

Sound signal apparatus is indicated by the appropriate word in capital letters (*HORN, BELL, GONG*, etc.) or an abbreviation indicating the type of sound. Sound signals of all types other than submarine sound signals are represented by three arcs of concentric circles within an angle of 45°, oriented and placed as necessary for clarity. The letters "**DFS**" indicate a **distance finding station** having synchronized sound and radio signals. The location of a sound signal which does not accompany a visual aid, either lighted or unlighted, is shown by a small circle and the appropriate word in vertical block letters.

Private aids, when shown, are marked "Priv maintd." Some privately maintained unlighted aids are indicated by a small circle accompanied by the word "Maker", or a larger circle with a dot in the center and the word "MARKER". The center of the circle indicates the position of the aid. A privately maintained lighted aid has the light symbol and is accompanied by the characteristics and the usual indication of its private nature. Private aids should be used with caution.

A *light sector* is the sector or area bounded by two radii and the arc of a circle in which a light is visible or in which it has a distinctive color different from that of adjoining sectors. The limiting radii are indicated on the chart by dotted lines.

Colors of the sectors are indicated by words spelled out if space permits, or by abbreviation (W, R, etc.) if it does not.

Limits of light sectors and arcs of visibility *as observed from a vessel* are given in the light lists, in clockwise order.

Land areas.—The amount of detail shown on the land areas of nautical charts depends upon the scale and the intended purpose of the chart.

Relief is shown by contours and form lines.

Contours are lines connecting points of equal elevation. The heights represented by the contours are indicated in slanting figures at suitable places along the lines. Heights are usually expressed in feet (or in meters with means for conversion to feet). The interval between contours is uniform over any one chart, except that certain intermediate contours are sometimes shown by broken line. When contours are broken, their locations are approximate.

Form Lines are approximations of contours used for the purpose of indicating relative elevations. They are used in areas where accurate information is not available in sufficient detail to permit exact location of contours. Elevations of individual form lines are not indicated on the chart.

Spot elevations are generally given only for summits or for tops of conspicuous landmarks. The heights of spot elevations and contours are given with reference to mean high water when this information is available.

When there is insufficient space to show the heights of islets or rocks, they are indicated by slanting figures enclosed in parentheses in the water area nearby.

Cities and roads. Cities are shown in a generalized pattern that approximates their extant and shape. Street names are generally not charted except those along the waterfront on the largest scale charts. In general, only the main arteries and thoroughfares or major coastal highways are shown on smaller scale charts. Occasionally, highway numbers are given. When shown, trails are indicated by a light broken line. Buildings along the waterfront or individual ones back from the waterfront but of special interest to the mariner are shown on large-scale charts. Special symbols are used for certain kinds of buildings, as indicated in part I of Chart No. 1. Both single and double track railroads

are indicated by a single line with cross marks. In general, city electric railways are not charted. A fence or sewer extending into the water is shown by a broken line, usually labeled. Airports are shown on small-scale charts by symbol and on large-scale charts by shape and extent of runways. Breakwaters and jetties are shown by single or double lines depending upon the scale of the chart. A submerged portion and the limits of the submerged base are shown by broken lines.

Landmarks are shown by symbols, as given in Chart No. 1.

A large circle with a dot at its center is used for selected landmarks that have been accurately located. Capital letters are used to identify the landmarks: HOUSE, FLAGPOLE, STACK, sometimes followed by "(conspic)".

A small circle without a dot is used for landmarks not accurately located. Capital and lower case letters are used to identify the landmark: Mon, Cup, Dome. The abbreviation "PA," for position approximate, is used when necessary as a safely feature.

When only one object of a group is charted, its name is followed by a descriptive legend in parenthesis, including the number of objects in the group, for example **(TALLEST OF FOUR)** or **(NORTHEAST OF THREE)**.

Some of the accompanying labels on a chart are interpreted as follows:

Building or **house.** One of these terms, as appropriate, is used when the entire structure is the landmark, rather than an individual feature of it.

A **spire** is a slender pointed structure extending above a building. It is seldom less than two-thirds of the entire height of the structure, and its lines are rarely broken by stages or other features. The term is not applied to a short pyramid-shaped structure rising from a tower or belfry.

A **cupola** (ku'po. la) is a small dome-shaped tower or turret rising from a building as the following figure.

A **dome** is a large, rounded, hemispherical structure rising above a building, or a roof of the same shape. A prominent example is that of the Capital of the United States, in Washington, D.C.

A **chimney** is a relatively small, upright structure projecting above a building for the conveyance of smoke.

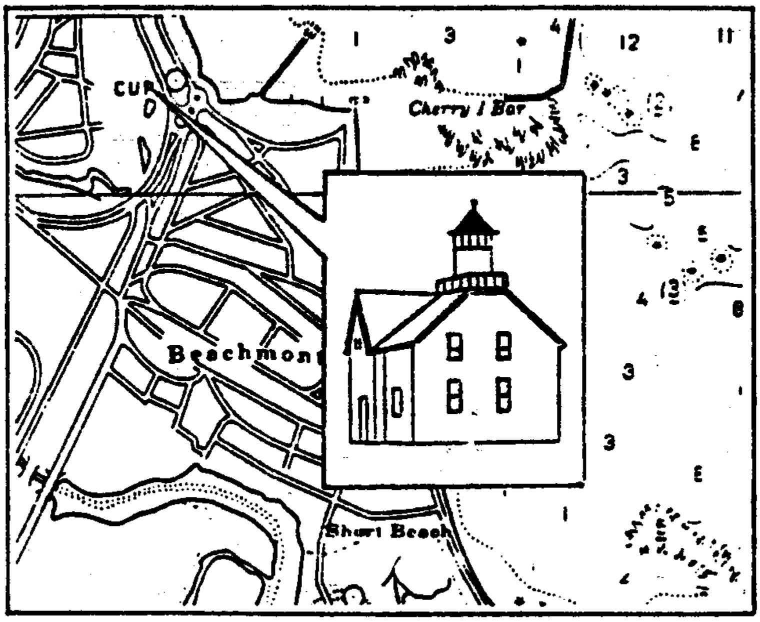
A stack is a tall smokestack or chimney. The term is used when the stack is more prominent as a landmark than accompanying buildings.

A **flagpole** is a single staff from which flags are displayed. The term is used when the pole is not attached to a building.

The term **flagstaff** is used for a flagpole rising from a building.

A **flag tower** is a scaffold-like tower which flags are displayed.

A **radio tower** is a tall pole or structure for elevating radio antennas.



A cupola

A **radio mast** is a relatively short pole or slender structure for elevating radio antennas, usually found in groups.

A **tower** is any structure with its base on the ground and high in proportion to its base, or that part of a structure higher than the rest, but having essentially vertical sides for the greater part of its height.

A **lookout station** or **watch tower** is a tower surmounted by a small house from which a watch is kept regularly.

A **water tower** is a structure enclosing a tank or standpipe so that the presence of the tank or standpipe may not be apparent.

A **standpipe** is a tall cylindrical structure, in a waterworks system, the height of which is several times the diameter.

The term **tank** is used for a water tank elevated high above the ground by a tall skeleton framework.

The expression **gas tank** or **oil tank** is used for the distinctive structures described by these words.

Miscellaneous.—*Measured mile*. A measured nautical mile indicated on a chart is accurate to within 6 feet of the correct length. Most measurements in the United States were made before 1959, when the United States adopted the International Nautical Mile. The new value is within 6 feet of the previous standard length of 6,080.20 feet, adjustments not having been made. If the measured distance differs from the standard value by more than 6 feet, the actual measured distance is stated and the words "measured mile" are omitted.

Periods after abbreviations in water areas are omitted, as these might be mistaken for rocks. However, a lower case *i* or *j* is dotted.

Courses shown on charts are given in true directions, to the nearest minute of arc.

Bearings shown are in true directions *toward* (not from) the objects.

Commercial radio broadcasting stations are shown on charts when they are of value to the mariner either for obtaining radio bearings or as landmarks.

Rules of the road. Lines of demarcation between the areas in which international and inland navigation rules apply are shown only when they cannot be adequately described in notes on the chart.

Compass roses are placed at convenient locations on Mercator charts to facilitate the plotting of bearings and courses. The outer circle is graduated in degrees with zero at true north. The inner circle is graduated in points and degrees with the arrow indicating magnetic north.

Magnetic information. On many charts magnetic variation is given to the nearest 15' by notes in the centers of compass roses; the annual change is given to the nearest 1' to permit correction of the given value at a later date. When this is done, the magnetic information is updated when a new edition is issued. The current practice of the Defense Mapping Agency Hydrographic/Topographic Center is to give the magnetic variation to the nearest 1', but the magnetic information on new editions is only updated to conform with the latest (1980.0, 1985.0,etc.).

Whenever a chart is reprinted, the magnetic information is updated to the latest epoch. On other charts the variation is given by a series of **isogonic lines** connecting points of equal variation, usually a separate line being given for each degree of variation. The line of zero variation is called the **agonic line**. Many plans and insets show neither compass roses nor isogonic lines, but indicate magnetic information by note. A local magnetic disturbance of sufficient force to cause noticeable deflection of the magnetic compass, called **local attraction**, is indicated by a note on the chart.

Currents are sometimes shown on charts by means of arrows giving the directions, and figure giving the speeds. The information thus given refers to the usual or average conditions, sometimes based upon very few observations. It is not safe to assume that conditions at any given time will not differ considerably from those shown.

Longitude are reckoned eastward and westward from the meridian of Green-wich, England, unless otherwise stated.

Notes on charts should be read with care, as they may give important information not graphically presented. Several types of notes are used. Those in the margin give such information as the chart number and (sometimes) publication and edition notes, identification of adjoining charts, etc. Notes in connection with the chart title include such information as scale, sources of charted data, tidal information, the unit in which soundings are given, cautions, etc. Another class of notes is that given in proximity to the detail to which it refers. Examples of this type of note are those referring to local magnetic disturbance, controlling depths of channels, measured miles, dangers, dumping grounds, anchorages, etc.

Overlapping charts constructed on different horizontal geodetic datums (app. X) may carry the following note:

CAUTION

Differences in latitude and longitude may exist between this and other charts off the area; therefore, the transfer of positions from one chart to another should be done by bearings and distances from common features.

Horizontal geodetic datum shifts may be given to provide the corrections necessary to shift to a different datum (app. X). It is the practice of the Defense Mapping Agency Hydrographic/Topographic Center to provide, if plottable, the corrections to new charts and new editions of charts that are necessary to shift the geodetic datum to the World Geodetic System.

Anchorage areas are shown within purple broken lines and labeled as such. Anchoring berths are shown as purple circles with the number or letter assigned to the berth inscribed within the circle. Caution notes are sometimes shown when there are specified anchoring regulations.

Spoil areas are shown within short broken black lines. The area is tinted blue (National Ocean Service charts only) and labeled **SPOIL AREA**.

Firing and bombing practice areas in the United States territorial and adjacent waters are shown on National Ocean Service charts and Defense Mapping Agency Hydrographic/Topographic Center charts of the same area and comparable scale. Danger areas established for short periods of time are not charted, but are announced locally. Danger areas in effect for longer periods are published in the *Notice to Mariners*. Any aid to navigation established to mark a danger area or a fixed or floating target is shown on charts.

Traffic separation schemes show routes to increase safety of navigation, particularly in areas of high density shipping. Traffic separation schemes are shown on standard nautical charts of scale 1:600,000 and larger and are printed in purple. The arrows printed on charts to indicate tracks are intended to give the general direction of traffic only, ships need not set their courses strictly by the arrows. At points where several recommended routes meet, circular or triangular separation zones with traffic direction arrows are shown.

Recommended tracklines, portrayed in black, are used to indicate suggested courses through particular passages and are selected according to their value for oceangoing ships.

A logarithmic time-speed-distance nomogram with an explanation of its application is shown on harbor charts at scales of 1:40,000 and larger.

Tidal boxes (the following figure) are shown on charts of scales 1:75,000 and larger.

TIDAL INFORMATION

Place	Position		Height above datum of soundings			
			Mean High Water		Mean Low Water	
	N. Lat.	E. Long.	Higher	Lower	Lower	Higher
			meters	meters	meters	meters
Olongapo.......	14°49′	120°17′	...0.9...	... 0.4...	...0.0...	.. 0.3....

Tidal box

Tabulation of Controlling depths (Page 134) are shown on National Ocean Service harbor charts.

Title. The chart title may be at any convenient location, usually in some area not important to navigation. It is composed of several distinctive parts as shown in Page 135.

Reproductions of Foreign Charts

Modified facsimile charts are modified reproductions of foreign charts produced in accordance with bilateral agreements. Such agreements serve to provide the mariner with more up-to-date charts.

Modified facsimile charts published by the Defense Mapping Agency Hydrographic/Topographic Center are, in general, reproduced with minimal changes. Such changes may include all or part of the following:

1. The original name of the chart is removed and replaced by an anglicized version
2. English language equivalents of names and terms on the original chart are printed in a suitable glossary on the reproduction, as appropriate.
3. All hydrographic information, except bottom characteristics, is shown as depicted on the original chart.

4. Bottom characteristics are shown as depicted in Chart No. 1.
5. The unit of measurement used for soundings is shown in block letters outside the upper and lower neatlines.
6. A scale for converting charted depth to feet, meters, or fathoms is added.
7. A blue tint is shown from a significant depth curve to the shoreline.
8. A blue tint is added to all dangers enclosed by a dotted danger curve.
9. A blue tint is added to dangerous wrecks, foul areas, obstructions, rocks awash, sunken rocks, and swept wrecks.
10. Aids to navigation, landmarks, and special area symbols and abbreviations on the original chart are changed to conform with Chart No. 1.

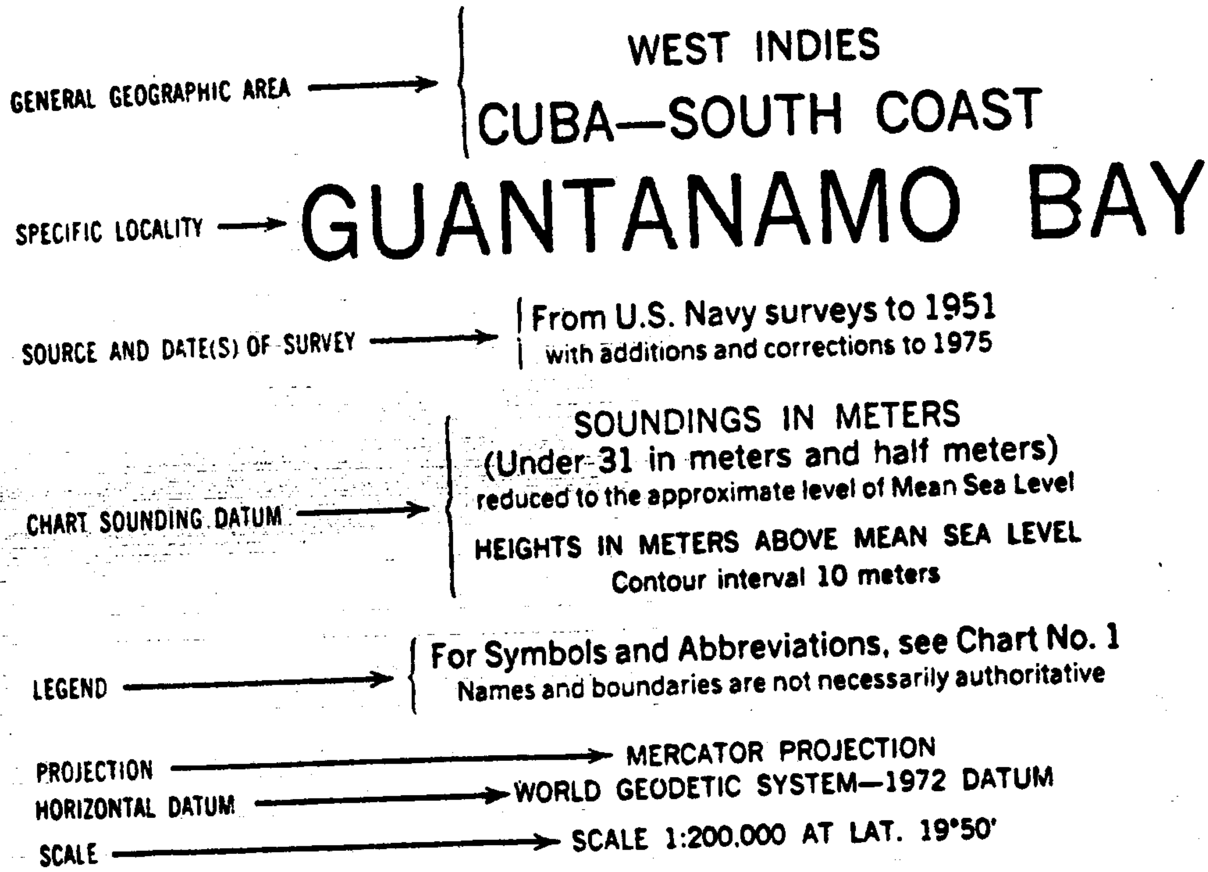
NANTUCKET HARBOR

Tabulated from surveys by the Corps of Engineers - report of June 1972 and surveys of Nov. 1971

Controlling depths in channels entering from seaward in feet at Mean Low Water					Project Dimensions		
Name of Channel	Left outside quarter	Middle half of channel	Right outside quarter	Date of Survey	Width (feet)	Length (naut. miles)	Depth M.L.W. (feet)
Entrance Channel	11.1	15.0	15.0	11-71	300	1.2	15

Note.-The Corps of Engineers should be consulted for changing conditions subsequent to the above

Tabulations of controlling depths.



A chart title

11. Caution notes are shown in purple and enclosed in a box.
12. Restricted, danger, and prohibited areas are usually outlined in purple and labeled "**RESTRICTED AREA**", "**DANGER AREA**", etc.
13. Traffic separation schemes are shown in purple.
14. A note on traffic separation schemes, printed in purple, is added to the chart.
15. Wire dragged (swept) areas are shown in purple or green.
16. If plottable, suitable corrections are provided to shift the horizontal datum to the World Geodetic System (1972).

International charts.—The need for mariners and chart makers to understand and use nautical charts of different nations became

increasingly apparent during the late 19^{th} and 20^{th} centuries as the maritime nations of the world developed their own establishments for the compilation and publication of nautical charts from hydrographic surveys. There followed a growing awareness that international standardization of symbols and presentation was desirable, which led to 22 maritime nations sending their representatives to Hydrographic Conference in London in 1919. That conference resulted in the establishment of the International Hydrographic Bureau (IHB) in Monaco in 1921, where the seat of the International Hydrographic Organization (IHO), with a membership of over 40 States remains today.

Recognizing that there was considerable duplication of effort by various Member States when each was charting the same parts of the ocean, and being conscious of the significant level of standardization in chart symbolization which had been reached, a move was made by the **IHO** in 1967 to introduce the first international chart. A Committee of representatives from six Member States was organized which reported in 1970. The Committee drew up plans and specifications for two series of international charts of the oceans on scales 1:10,000,000 and 1:3,500,000, respectively. The limits of each of some 83 of these charts, giving worldwide small scale navigational cover, were agrees, and responsibility for compiling each of these has subsequently been accepted by Member States' Hydrographic Offices.

Once a Member State publishes an international chart, reproduction material is made available to any other Member State which wish to print the chart for its own purposes.

International charts can be identified by the letters **INT** before the chart number and the International Hydrographic Organization seal in addition to what other seals may appear on the chart.

Chart Numbering System

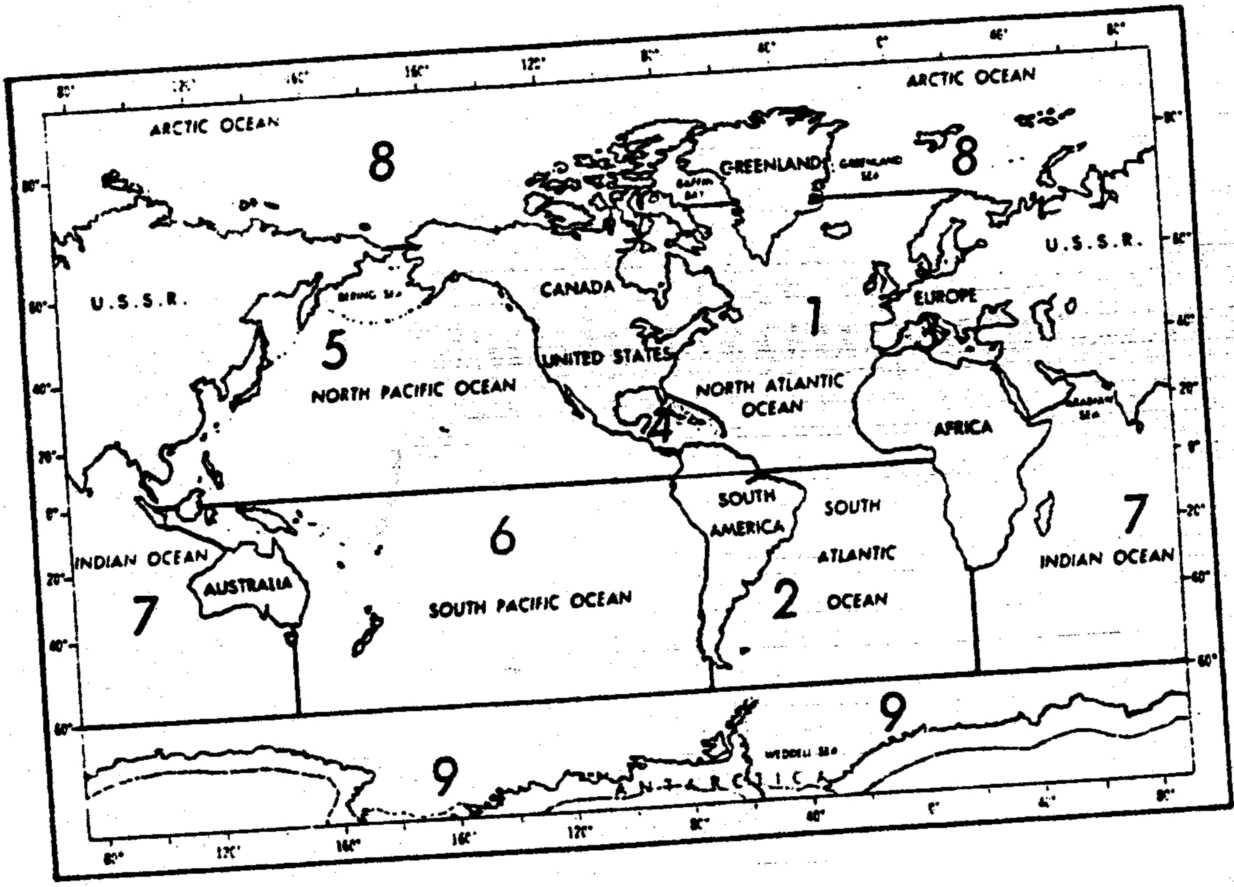
Chart numbering system.—The numbering of nautical charts produced and issued by the Defense Mapping Agency Hydrographic/Topographic Center and the National Ocean Service is based on a system in which numbers are assigned in accordance with the scale range and geographical area of coverage of a chart. With the

exception of certain charts produced for military use only, one- to five-digit numbers are used. And with the exception of one-digit numbers, the first digit identifies the area; the number of digits establishes the scale range (the following figure). The *one-digit numbers* are used for products in the chart system which are not actually charts, such as Chart No. 1, *Nautical Chart Symbols and Abbreviations*, chart 5, *National Flags and Engines*, and foreign symbols and abbreviations sheets for military use.

Number of Digits	Scale
1	No Scale
2	1:9,000,000 and smaller.
3	1:2,000,000 to 1:9,000,000.
4	Nonnavigational and special purpose.
5	1:2,000,000 and larger.

Scale ranges for number of digits in chart number

Two-and three-digit numbers are assigned to those small-scale charts which depict the major portion of an ocean basin or a large area, with the first digit identifying the ocean basin (the following figure). Two-digit numbers are used for charts of scale 1:9,000,000 and smaller. Three-digit numbers are used for charts of scale 1:2,000,000 to 1:9,000,000.



Ocean basins

Due to the limited sizes of certain ocean basins, no charts for navigational use at scales of 1:9,000,000 and smaller are published to cover these basins. The other-wise unused two-digit numbers (30 to49 and 70 to 79) are assigned to special world charts, such as chart 33, *Horizontal Intensity of the Earth's Magnetic Field*, chart 42, *Magnetic Variation, and chart 76, standard Time Zone Chart of the World.*

One exception to the scale range criteria for three-digit numbers is the use of three-digit numbers for a series of position plotting sheets which

are of larger scale than 1:2,000,000 because they have application in ocean basins and can be used in all longitudes.

Four-digit numbers are used for non navigational and special purpose charts, such as chart 5090, *Maneuvering Board*, chart 5101, Gnomonic Plotting Chart North Atlantic, and chart 7707, *Omega Plotting Chart*.

Five-digit numbers are assigned to those charts of scale 1:2,000,000 and larger that cover portions of the coastline rather than significant portions of ocean basins. These charts are based on the regions of the nautical chart index (Page 141).

The first of the five digits indicates the region; the Second digit indicates the subregion; the last three digits indicate the geographical sequence of the chart within the subregion. Many numbers have been left unused in order that future charts may be placed in their proper geographical sequence as they are produced.

In order to establish a logical numbering system within the geographical subregions (for the 1:2,000,000 and larger-scale charts), a worldwide skeleton framework of coastal charts was laid out at a scale 1:250,000. This skeleton series was used as basic coverage for the numbering except in area where a coordinated series at about this scale already existed. An example of an exception is the coast of Norway were a coordinated series of 1:200,000 coast charts is in existence. Within each region, the geographical subregions are numbered counterclockwise around the continents, and within each subregion the basic (1:250,000 skeleton)series also is numbered counterclockwise around the continents. The skeleton coverage is assigned generally every 20th digit, except that the first 40 numbers in each subregion are reserved for smaller-scale coverage. Charts with scales larger than the skeleton coverage are assigned one of the 19 numbers following the numbers assigned to the skeleton sheet within which it falls. Thus, charts on the west coast of the Iberian Peninsula and the northwest coast of Africa are numbered as shown in Page 142.

As shown in Page 142, five-digit numbers are assigned to the charts produced by other hydrographic offices. This numbering system is applied to foreign charts so that they can be field in logical sequence with

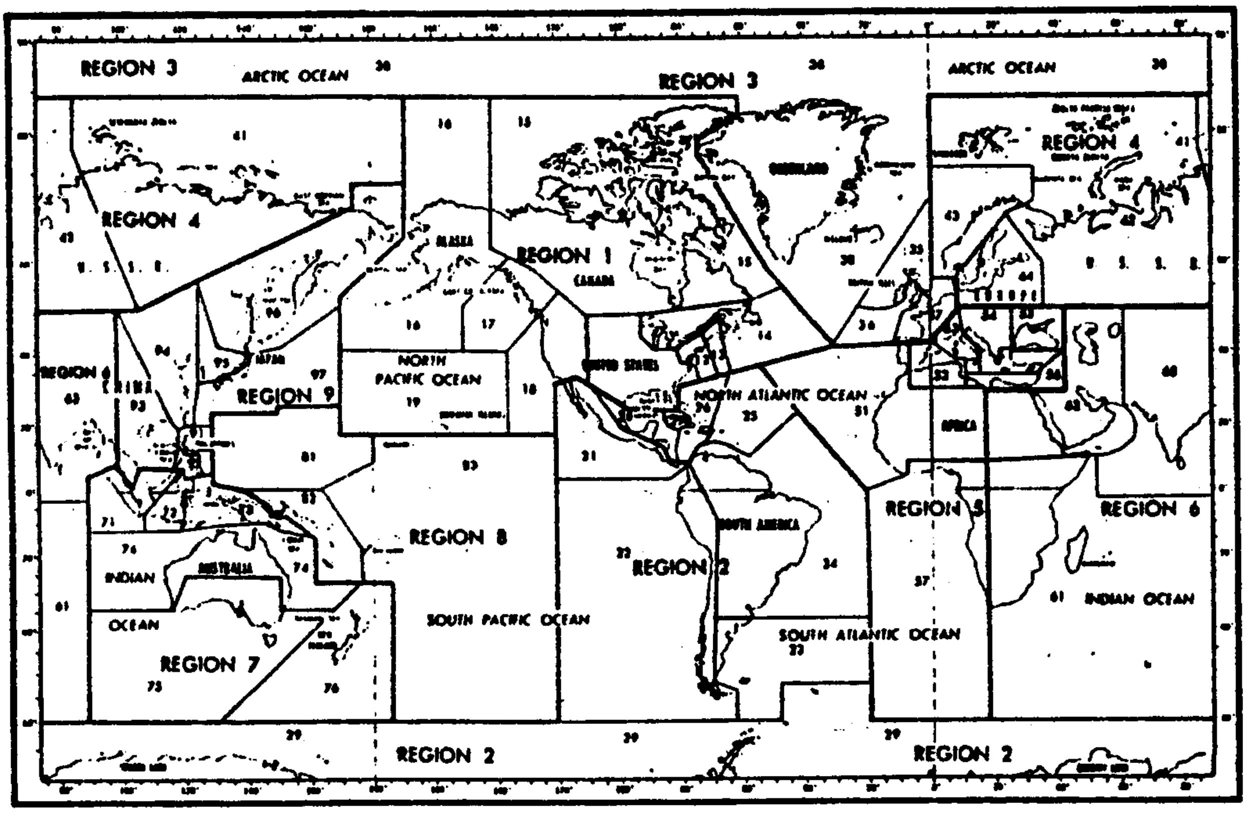
the charts produced by the Defense Mapping Agency Hydrographic/Topographic Center and the National Ocean Service.

Exception to the numbering system to satisfy military needs are as follows:

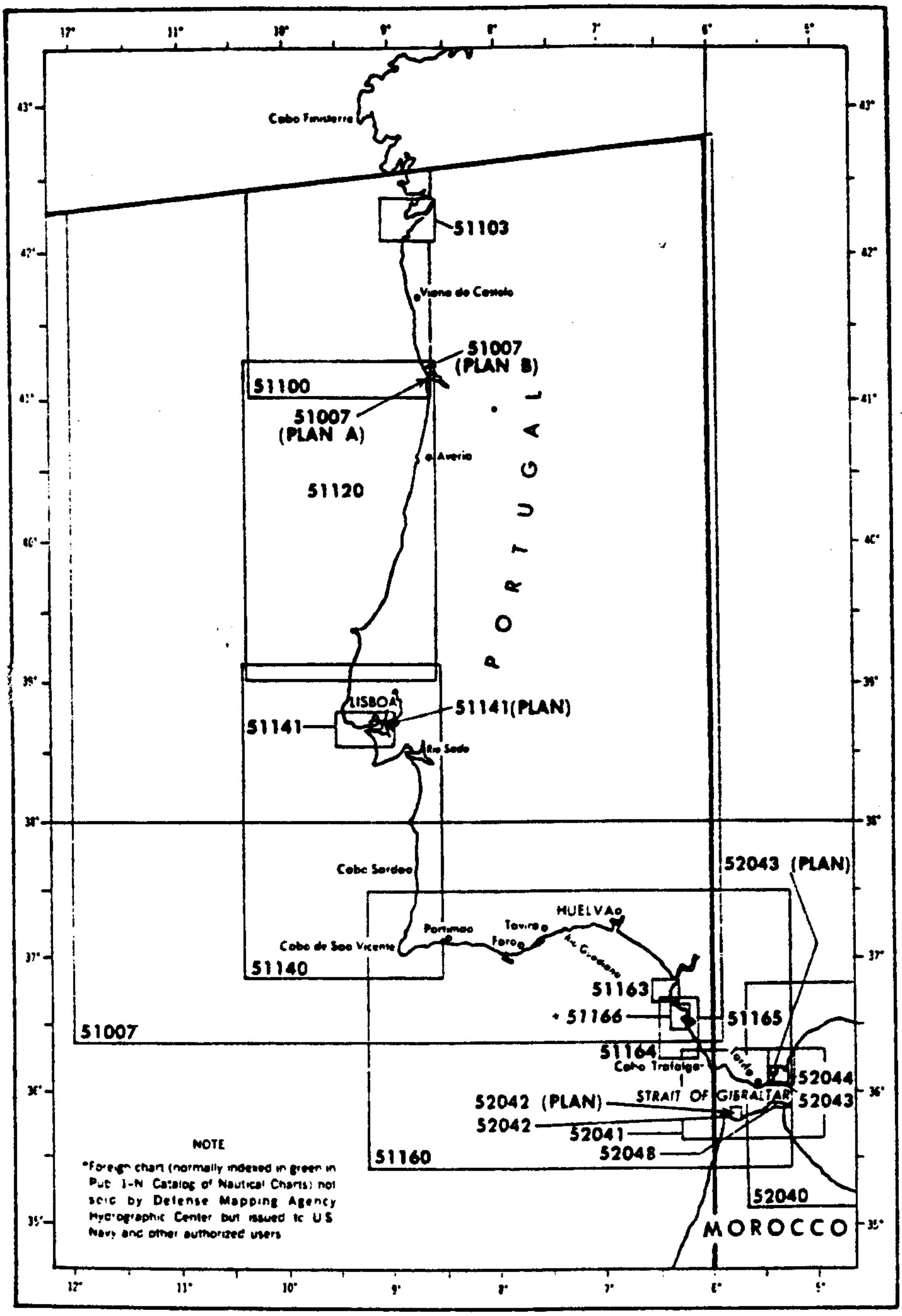
1. Bottom contour and non-submarine contact charts at a scale larger than 1:2,000,000 do not portray portions of a coastline but chart parts of the ocean basins. In view of the characteristics of these charts, they are identified with an alphabetical character plus four digits. All bottom contour charts will eventually be Omega versions only. The letter B denotes an interim version. The letter C denotes bottom contour charts with Loran-C information. The letter E denotes bottom contour charts with omega information.

2. Combat charts at a scale of 1:50,000, which would otherwise be assigned five-digit numbers, are assigned four digits separated by a letter of the alphabet. The first two digits indicate the region and subregion; the third character is a letter of the alphabet; the last two digits indicate the geographical sequence of the chart within the subregion.

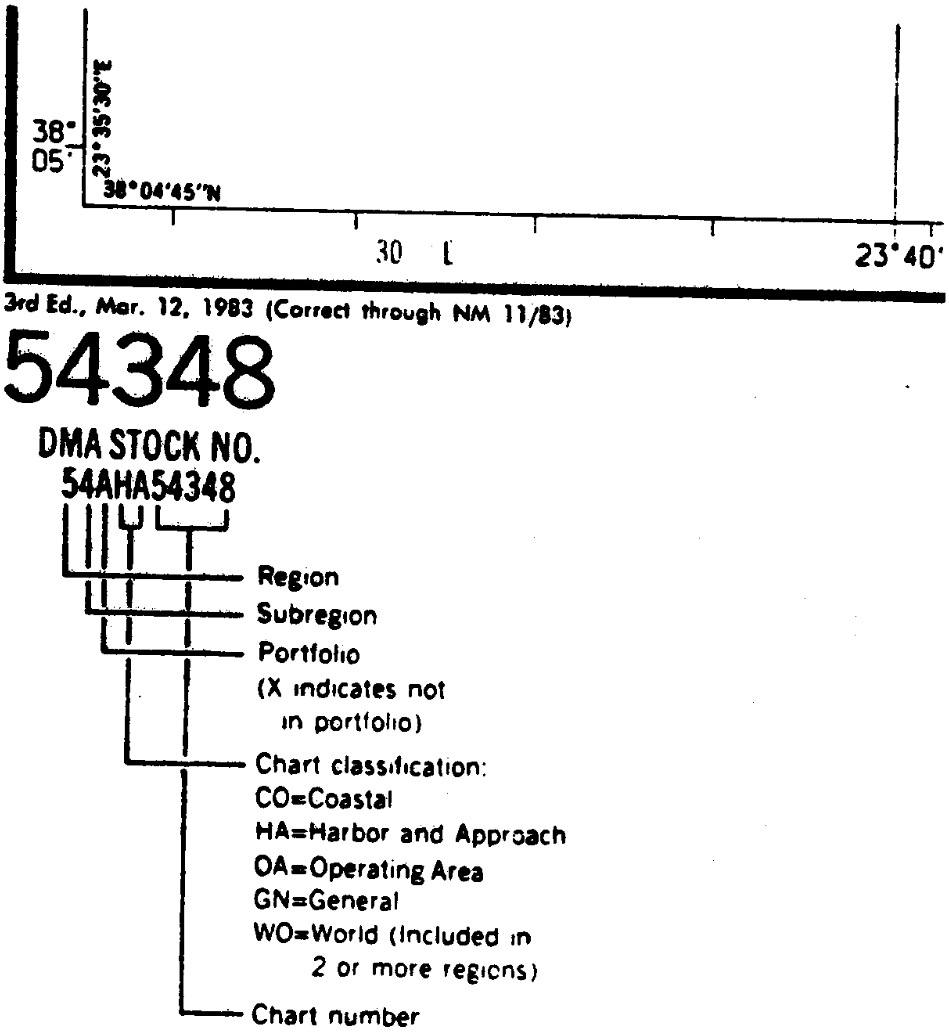
The Defense Mapping Agency stock number is shown in the lower left-hand corner of the chart directly under the chart number. The letters and numbers have chart significance as indicated in Page 143.



Regions and subregions of the nautical chart index.



Area of subregion 51 illustrating the numeral sequence of larger-scale charts along a coast



Defense Mapping Agency stock number.

Use of Charts

Advance preparation.—Before a chart is to be used, it should be studied carefully. All notes should be read and understood. There should be no question of the meanings of symbols or the unit in which depths are given, for there may not be time to determine such things when the ship is underway, particularly if an emergency should arise. Since the graduations of the latitude and longitude scales differ considerably on

various charts, those of the chart to be used should be noted carefully. Dangers and abnormal conditions of any kind should be noted.

Particular attention should be given to soundings. It is good practice to select a realistic danger sounding and mark this prominently with a colored pencil other than red.

It may be desirable to place additional information on the chart. Arcs of circles might be drawn around navigational lights to indicate the limit of visibility at the height of eye of an observer on the bridge. Notes regarding the appearance of light structures, tidal information, prominent ranges, or other information from the light lists, tide tables, tidal current tables, and sailing directions might prove helpful.

The particular preparation to be made depends upon the requirements and the personal preferences and experience of the individual navigator. The specific information selected is not important. But it is important that the navigator familiarize himself with his chart so that in an emergency the information needed will be available and there will be no question of its meaning.

Maintaining charts.—The print date in the lower left-hand corner of the chart is the date of the latest *Notice to Mariners* used to update to chart. Responsibility for maintaining it after this date lies with the user. *An uncorrected chart is a menace*. The various issues of *Notice to Mariners* subsequent to the print date contain information needed for maintaining charts. The more urgent items are also given in advance in the *Daily Memorandum* or by radio broadcast. A convenient way of keeping a record of the *Notice to Mariners* corrections made to each chart on hand is by means of the 5×8-inch *Chart/Publication Correction Record Card* (**DMAHTC** 8660/9).

Periodically **DMAHTC** publishes a *Summary of Corrections* containing previously published *Notice to Mariners* corrections.

When a new edition of a chart is published, it should be obtained and the old one retired from use. The very fact that a new edition has been prepared generally indicates that there have been changes that cannot adequately be shown by hand correction.

Use and stowage of charts.---Charts are among the most important aids of the navigator, and should be treated as such. When in use they

should be spread out flat on a suitable chart table or desk, and properly secured to prevent loss or damage. Every effort should be made to keep charts dry, for a wet chart stretches and may not return to the original dimensions after drying. The distortion thus introduced may cause inaccurate results when measurements are made on the chart.

Permanent corrections to charts should be made in ink so that they will not be inadvertently erased. All other lines should be drawn lightly in pencil so that they can be easily erased without removing permanent information or otherwise damaging the chart. To avoid possible confusion, lines should be drawn no longer than necessary, and adequately labeled. When a voyage is completed, the charts should be carefully and thoroughly erased unless there has been an unusual incident such as a grounding or collision, when they should be preserved without change, as they will undoubtedly be requested by the investigating authority. After a chart has been erased, it should be inspected carefully for possible damage and for incompletely erased or overlooked marks that might prove confusing when the chart is next used.

When not in use chart should be stowed flat in their proper drawers or portfolios, with a minimum of folding. The stowed charts be properly indexed so that any desired one can be found when needed. In removing or replacing a chart, care should be exercised to avoid damage to it or other charts.

A chart that is given proper care in use and stowage can have a long and useful life.

Chart lighting.--- In use of charts it is important that adequate lighting be provided. However, the light on the bridge of a ship underway at night should be such as to cause the least interference with the darkness-adaptation of the eyes of bridge personnel who watch for navigational lights, running lights, dangers, etc. Experiments by the Department of the Navy have indicated that red light is least distributing to eyes which have been adapted to maximum vision during darkness. In some instances red lights, filters, or goggles have been provided on the bridges or in chartrooms of vessels. However, the use of such light seriously affects the appearance of a chart. Red, orange, and buff disappear. Other colors may appear changed. This has led to the

substitution of nautical purple for red orange, and gray for buff on some charts. However, before a chart is used in any light except white, a preliminary test should be made and the effect noted carefully. If a glass or plastic top is provided for the chart table or desk, a dim white light below the chart may provide sufficient illumination to permit chart reading, without objectionable disturbance of night vision.

Use of small-craft charts.—Although the small-craft charts published by the National Ocean Service are designed primarily for boatmen, these charts at scales of 1:80,000 and larger are in some cases the only charts available of inland waters transited by large vessels. In other cases the small-craft charts may provide a better presentation of navigational hazards than the standard nautical chart because of scale and detail. *Therefore, it behooves navigators of large vessels transiting inland waters not to ignore the small-craft charts.*

Land Navigation :

It is well known that sea navigation concerning the motion of vessels on the sea and air navigation concerning aviation. No, doubt that the land navigation surved the motion of any vechichels on land. That is well occurred in petrolum drilling operations as well as the construction of new roads and in rail ways too. The land navigation could be divided into two following items:-

1- Desert navigation.
2- Forests navigation.

The desert navigation:

It is quite clear to all navigators that before any trip could be started there are same information should be prepared.

1 – The required charts which will be used for ploting.
2 – To draw the required courses which will lead to the destination.
3 – The morphological conditions of the courses.
4 – The topographic conditions of the area which the navigator will navigate through
5 – The areas which will be suitable for camping through the required mission.

6 – The navigational aids which the navigator can use it through the mission

Historically, since the ancient time the land navigation was knowned. That could be approved through the merchants trip for mutual their commodities with others elsewhere. For the reasons and other such as emigrations had let the cartographers to draw the charts which can help the land navigators did their trips safely. The following could explained the required information.

1 – The topographical conditions of land

There are a lot of information should be considered on the topographic charts, these information could be summarized as follows:-

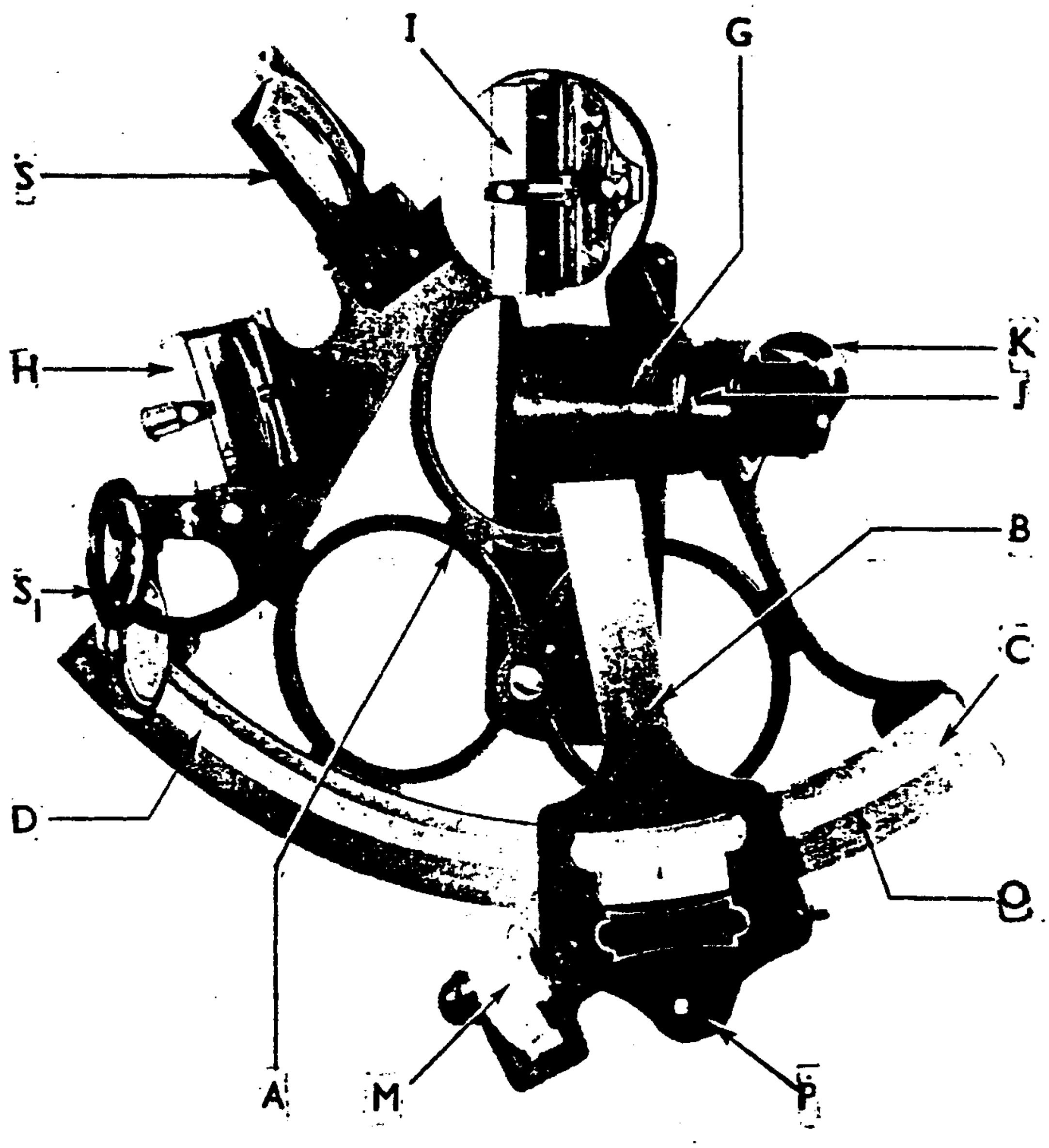
1-1The kind of lands if it is a muddy land or a sandy land or it is a rocky kinds. That shows methods which could be used during a certain trip to avoid the grounding of any vehicles on a sand bank. As well as the slipping of any vehicles in swamp areas or muddy one. For these reasons the factories which they manufactured vehicles designed a four wheel vehicles with special gearbox.

1-2 The heights and subdued lands, The topographic charts consists of quite explanation about the heights and subdued lands considering the measurements of the heights of the subdued lands in meters or in feets in relevant to the sea level. That to give the land navigator a clear sight during his trips while he is designing the trip courses.

1-3 The camping areas, In the exploring missions which may takes a long time, the explorers themselves needs rest for feedings and sleeping. For that the land navigators should select the suitable areas for camping operations during the mission.

That areas could be selected near by rivers or wells for getting the water, Some times these missions may afford the starving materials to their member from the stores which may be towed through the trip.

- The aids of land navigation.
- The magnetic compress.
- The topographic charts.
- Plotting instruments such as, dividers parallel rulers, pratractor.
- Sextant for measuring altitude.
- Distance – meter.



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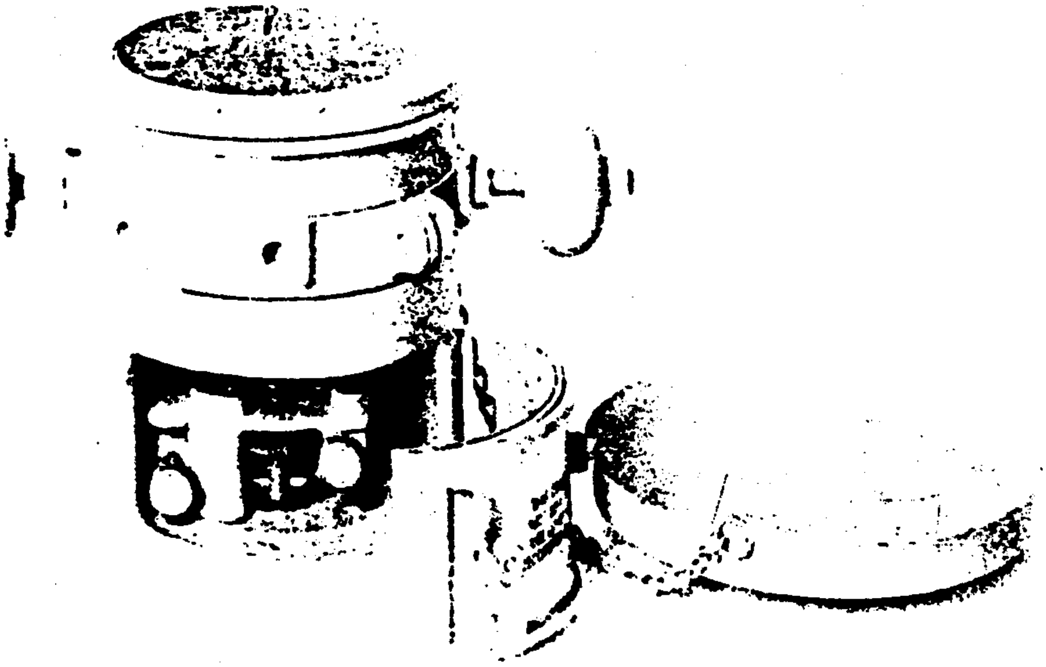
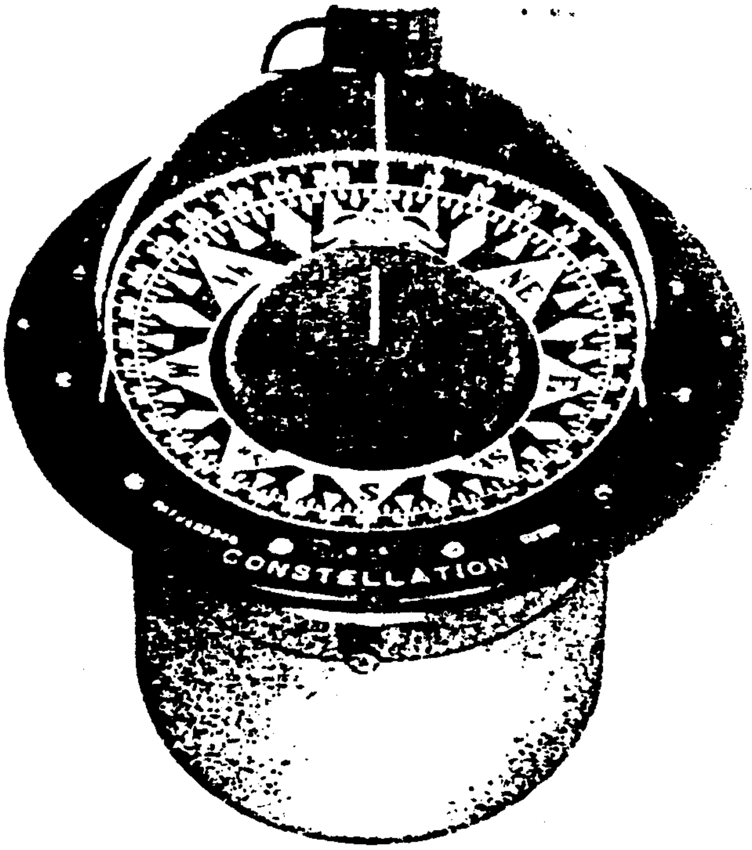
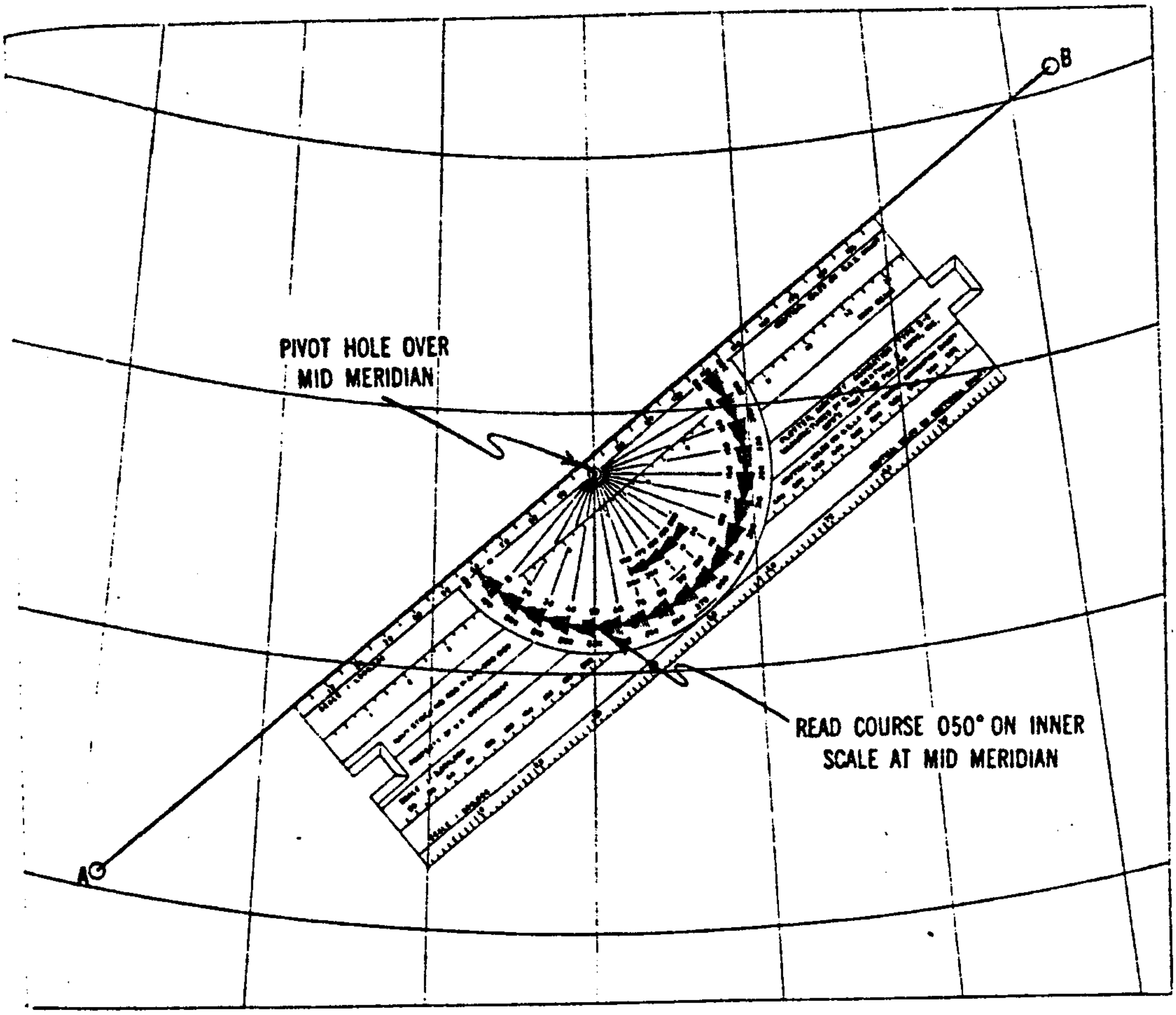


U.S. Navy No. 5 magnetic boat ompass.



Division of The Eastern Company, a Connecticut Corporation

A compass with a hemispherical top.



Measuring a course on a Lambert conformal chart by a B-2 aircraft plotter. Note that measurement is made at the mid meridian

Some notices during plotting :

1– Use the plotters when drawing the trip courses.
2- Select the initial position carefully and colour the location to be well clear.
3- Select the destination position and colour it with another colour.
4- Join, between position to gain the trip courses.
5- Draw the trip courses by using a sharp head pencils.
6- Draw the courses by using hard pencils to make the line very soft that it could be removed by using rubbers.
7- Use the protractors to measure the course angle on a chart.
8- Use a suitable scale to measure the distance between position and reverse it to the chart scale.
9- Write the distance between two position in a special table to be quite clear during operation.
10- Extract all information from the topographic charts on a special card.

- Forest navigation

The forest navigation is not different from land navigation. Due to the huge number of trees in a forest, the sight is repeatable for that, the selected course should be coloured with soft colours such as, white, yellow, orange, red and avoid graybrown and blue colours because these colours, may be interacted with forest's natural colours. It is very important to draw the colour of the selected course in the forest on the chart for reminding from where the mission started and to where the mission could came to an end.

Air Navigation

The air navigation concerning the airplane movements and the air traffic control management. The air transport depends on the following system.
1- The air port and its campases.
2- The airplane and its operation management.
3- The aids to navigation.
4- The air line.
5- The crews.

At present time the air transport plays a major roll in passenger field. This type of transport can not be compite with other modes of transport due to the very short time which can be used in any trip. The long distance airplane cover the distance between. Cairo [The Egyptian Capital] and New York [one of the biggest country in U.S.A.] in 12 hours in a non stop trip. In a passenger vessel can cover the same distance in a three weeks time. For the reason of the short time in air transport many passenger vessels lost its markets.

On the following line, you will find the explanation of air transport system.

The air port campases

The air port consists of the following :-

1- The passenger reception halls.
2- The emigration and passport control counters
3- Costumes clearance offices.
4- The traffic control tower.
5- The airplane parking and maintenance areas.
6- The take off - landing fairway
7- The weather forecast stations.

Also in the airport there are restaurants, hotels, free shops and special yards for exhibitions

The airplane operation system.

There are many types of airplane, such as passenger airplane and others used for cargo. There are many air lines owned airplanes and announced for its schedules to let passengers used to proper line to deliver him to his destination, others having chartered airplanes. All airplanes having maintenance plane and log book to count the hours which the airplanes flight, ht, for checking up purposes.

The aids to navigation system

To any air port there is a light house is used to declare the airplanes approach. The light house always painted with a special paint to let the

pilots distinguish it for approach purposes, at night there is a special light could help the pilots in night flight. The passage way marked with white strips at where the aeroplane could start its take of or landing and at night the bankes of the passage way is marked with special lights which could be used to declare the edges of the passage boarders.
The control tower distribute the air corridors to airplanes for the safety purposes. Also the heights of flights is well controlled to distinguish between the sizes of airplanes. There are a lot of means of communications to communicate any aeroplanes arround the earth to increase the safety between airplanes in the air and between any two air ports.

At present the air traffic management having a wide progress for the safety purposes.

- The aeroplanes pilots and crew members.

On the airplane there are one pilot and his assistant. The pilots and their assistances they are responsible for take off and landing operations and the pilot is the master of the airplane. He is responsible for every crew members as well as the passengers too. He communicate the air ports for landing and take off management operations. He is responsible for all safety management on board the craft to fly safely from an air port to another. The crew members are responsible for all hostels works for the seek of passengers.

The space navigation

The space navigation used the air navigation and after crossing the earth's atmosphere the navigation became a space navigation.
No doubt, that the space navigation is very complex operations and very accurate systems which are very advanced. These systems are used in plotting operations. The space shattle nowadays, is used to transport through space stations and satellites which are widely used in several purposes such as scouting, televisions and communications.

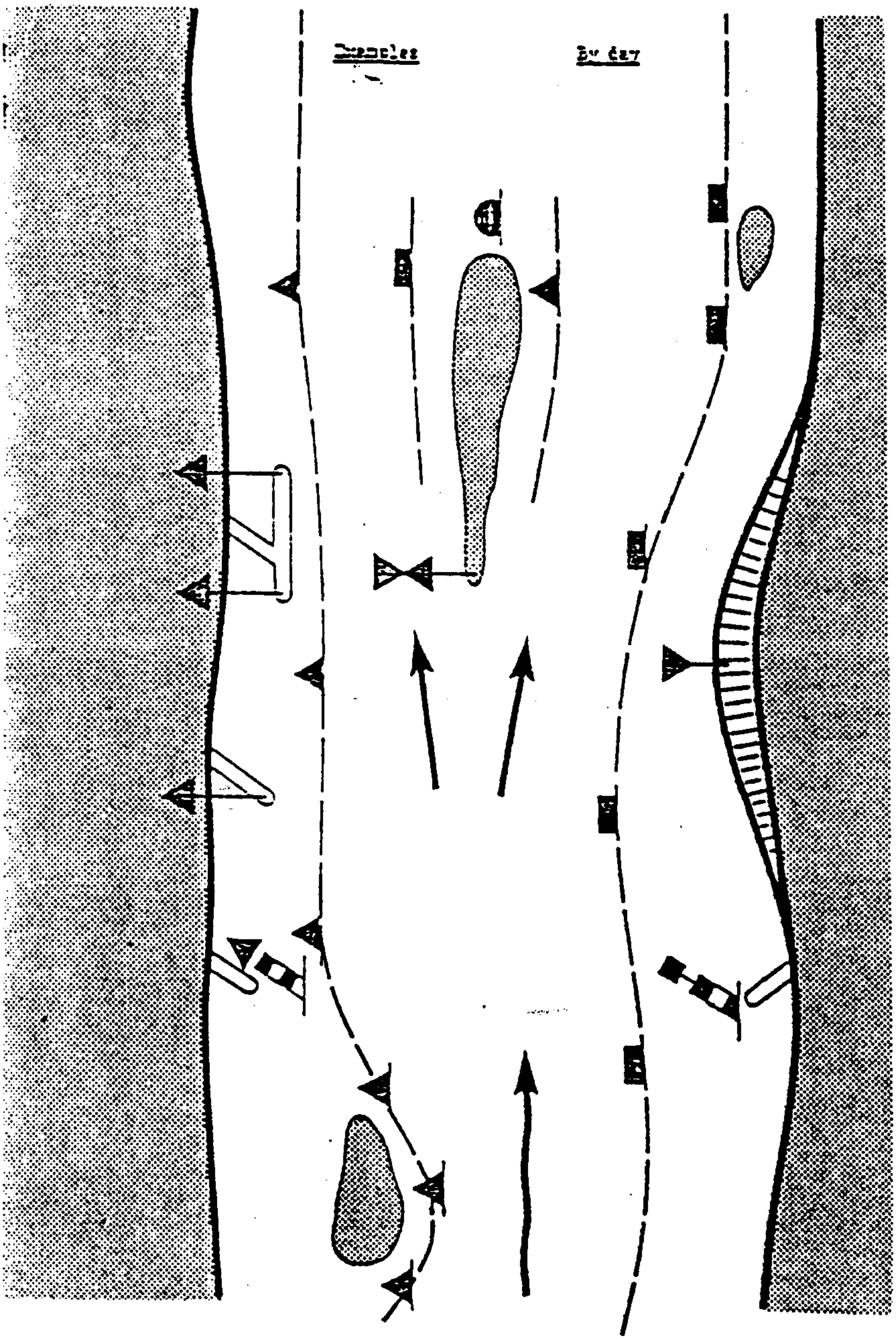
The narrow water navigation

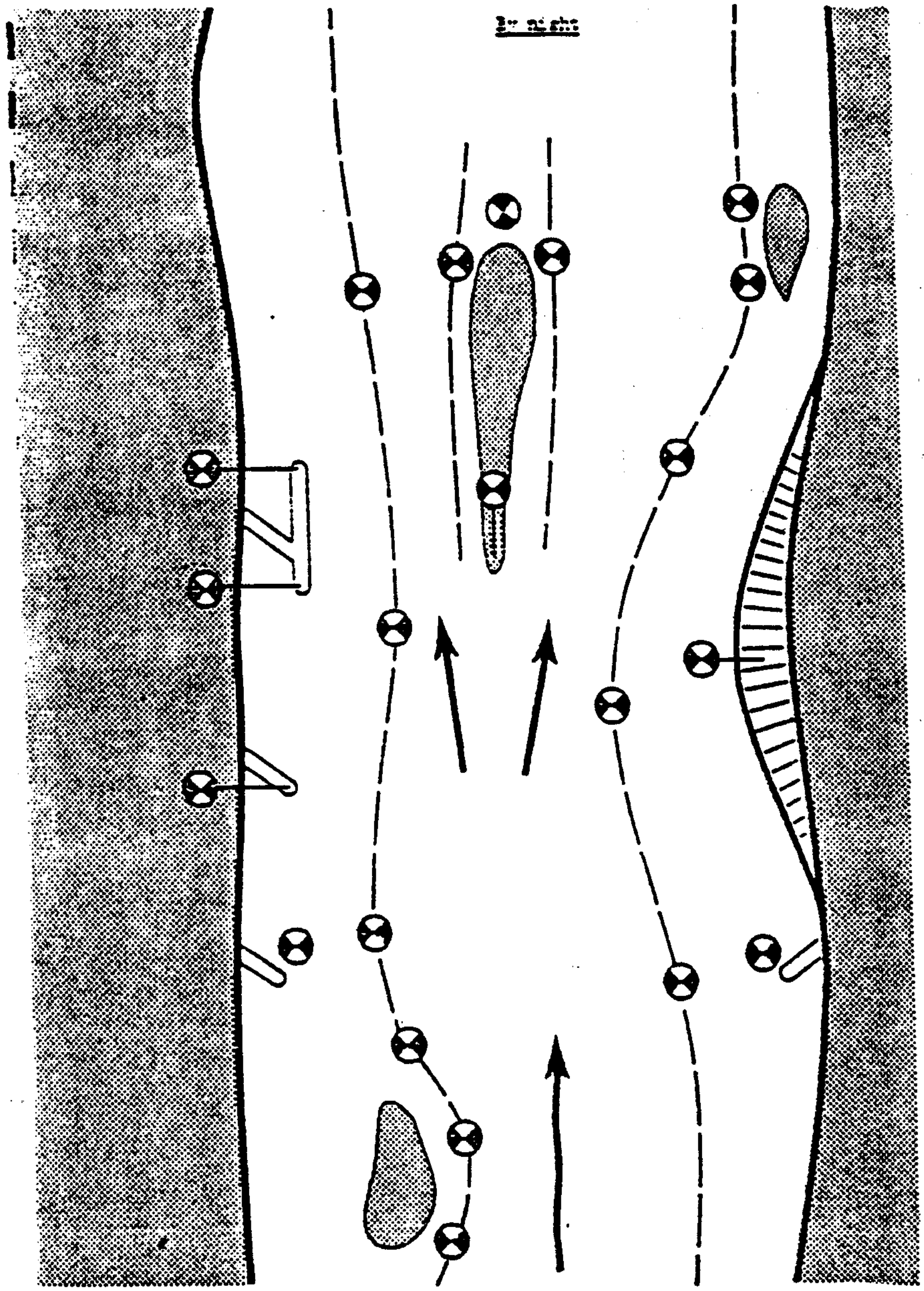
This kind of navigation requires a very high attention from navigators during sailing operations. The master of vessels should have a certain

skill in ship handling to control the vessel's movements during sailing to avoid any stranding or grounding incidents. For the reasons of safety navigation, the authority of any narrow water should marked her channels with aids to navigation to facilitate the navigation processes. This aids to navigation system consists of many water and land marks such as the following :-

- Distance marks.
- Traffic direction marks.
- Lock marks.
- Anchor marks.
- Fuel marks.
- Side marks.
- Safe water marks.
- Dangerous marks.

The positions of the aids to navigation should be alocated on the navigational charts to let the masters steamed their vessels safely (see the following charts).




By night

CHAPTER IV

OCEANIC SOUNDINGS HYDROGRAPHIC REPORTS

CHAPTER IV
OCEANIC SOUNDINGS AND HYDROGRAPHIC REPORTS
General

Introduction.—Maritime shipping continues to increase with the growth in volume of domestic and international commerce, and seagoing vessels continue to increase in number, size, and speed. Not only does this growth result in constant demands for expansion and improvement of harbor, port, and navigation facilities, but it also necessitates improvements in the quality , quantity, and display of all forms of navigation information.

Although both government agencies and private institutions operate as many oceanographic and hydrographic ships as their resources permit, the magnitude of requirements for information far exceeds the collection capabilities of these comparatively few vessels. It is not possible for any hydrographic institute to conduct a continuous worldwide survey. Consequently, the Defense Mapping Agency Hydrographic/Topographic Center and the National Ocean Service depend to a very great extent upon reports from voluntary seagoing observers for information pertaining to navigation and oceanography. Information from these reports and other sources is evaluated and used in the improvement, production, correction, and maintenance of charts and publications. After careful analysis of a report and comparison with all other data concerning the same area or subject, appropriate action is taken. If the report is of sufficient importance to affect the immediate safety of navigation, the information will be broadcast as a navigational warning. Each bit of information, no matter how trivial it may seem, is coordinated with other reports and used in some way in the compilation, construction, and correction of charts and publications. It is only through the constant flow of new information that charts and publications can be kept accurate and up-to-date.

Discrepancies are sometimes found in source material, mainly as a result of comparison with the reports submitted by mariners who have recently visited the area. Often, errors in basic source material are of the type that would affect the safety of navigation. Several confirming ship reports will usually reveal these errors so that corrective action can be

taken . The greater the volume of confirming ship reports, the greater is the accuracy of the finished product.

Marine reports.—Frequently the most valuable information is recent information reported by a mariner, who records the information in the greatest detail possible and reports it promptly.

Depending on the type of report, certain items of information are absolutely essential for a correct evaluation. An example is the state of tide. State of tide is of paramount importance in a report of near shore shoals; but of no interest with respect to shoals reported beyond the continental shelf.

Several reasons have been found for hesitancy on the part of the mariner to report his observations. He is frequently in doubt as to what information, and in what detail, to report. He often believes that the data that he reports will be inconsequential to the Defense Mapping Agency Hydrographic/Topographic Center since "they already receive the most recent information available, and they are already aware of this data", as one mariner put it.

Excellence in grammar is unnecessary. Reports, or supplemental information, such as port plans, obtained locally, may even be in a foreign language. Observations should be reported in the language of mariners since they will be evaluated by ex-mariners, who will make full and appropriate use of the information.

Reports by letters are just as acceptable as those prepared on regular forms. In some instance, a letter report will permit greater flexibility in reporting details, conclusions, or recommendation concerning the observation. When using the regular report forms, one should not hesitate to use additional sheets to complete the details of his observation. One should never be reluctant to report in detail.

The following general suggestions are offered as an aid to marking reports that will be of maximum value.

1. The geographical position included in the report may be used in the correction of charts. Accordingly, it should be fixed by the most accurate method available. If practicable, the position should be verified by additional means.

2. The report should state the method by which the position was fixed, so that the degree of accuracy can be established.
3. When reporting the position of an object or condition that is not shown on the chart but is within sight of charted objects, the simplest and most accurate method is to express the position in terms of bearings and distances from charted objects.
4. Should geographical coordinates be used to report position, they should be made as precise as circumstances permit. Either tenths of a minute or seconds, depending upon the scale of the chart, should be included. Unfortunately, coordinates of all charts for a given area are not always in exact agreement. Accordingly, one should refer to the chart by number and include the edition number and the date of the printing being used. Both are shown in the bottom margin.
5. When describing the sectors in which a light is either visible or obscured, the limiting bearings from the ship towards the light should be given. Although this is just the reverse of the form used for locating objects, it is the standard method used by the hydrographic institutes of practically all countries.
6. All bearings used in reports should be *true* bearings, expressed in degrees. Should magnetic bearings be used, for any reason, such use stated in the report.
7. A report prepared by one person should, if practicable, be checked by another.

In most cases marine information can be adequately reported on one of various forms printed by the Defense Mapping Hydrographic/Topographic Center and shown in *Guide to Marine Observing and Reporting* or by the reporting sheet in the weekly *Notice to Mariners*. However, in some cases it is both more convenient and more valuable to annotate information directly on the affected chart and mail the chart to DMAHTC.

As an example, new construction, such as port facilities, may be drawn on the chart in cases where a written report would be inadequate. Another example would be a chart showing the tracking and pertinent soundings through a critical passage or strait when the ship's draft is close to the controlling depth of the water in the passage of strait. Information,

such as times, state of tide, draft, and method by which fixes were obtained should also be included.

Whenever it is necessary to send a chart to amplify or explain a report, the Defense Mapping Hydrographic/Topographic Center, upon request, will replace the chart free of charge on a one-for-one basis.

Urgent reports by radio.---*The International Convention for the Safety of Life at Sea* (1960), which is applicable to all U. S. flag ships, requires: "The master of every ship which meets with dangerous ice, or dangerous derelict, or any other direct danger to navigation, or a tropical storm, or encounters sub-freezing air temperatures associated with gale force winds causing severe ice accretion on superstructures, or winds of force 10 or above on the Beaufort scale for which no storm warning has been received, is bound to communicate the information by all the means at his disposal to ships in the vicinity, and also to the competent authorities at the first point on the coast with which he can communicate".

The master must first warn ships in the vicinity and must then report the danger to competent authorities at the first point on the coast with which radio contact can be made, using relay procedure if necessary. The report should be broadcast first on 500 kHz prefixed by the Safety Signal "TTT TTT TTT". This should be followed by transmission of the message to the proper authorities ashore.

Details on reporting via radio are contained in chapters 4 and 5 of Pubs. Nos.117A and 117B, *Radio Navigational Aids.*

***Guide to Marine Observing and Reporting*, Pub. 606**, prepared jointly by the Naval Oceanographic Office, the Defense Mapping Agency Hydrographic/Topographic Center, U. S. Coast Guard, and the National Oceanic and Atmospheric Administration, provides detailed guidance for submitting hydrographic and oceanographic reports. Where appropriate, this guidance includes check lists of key questions as a means of insuring that no essential fact will be missing from a report.

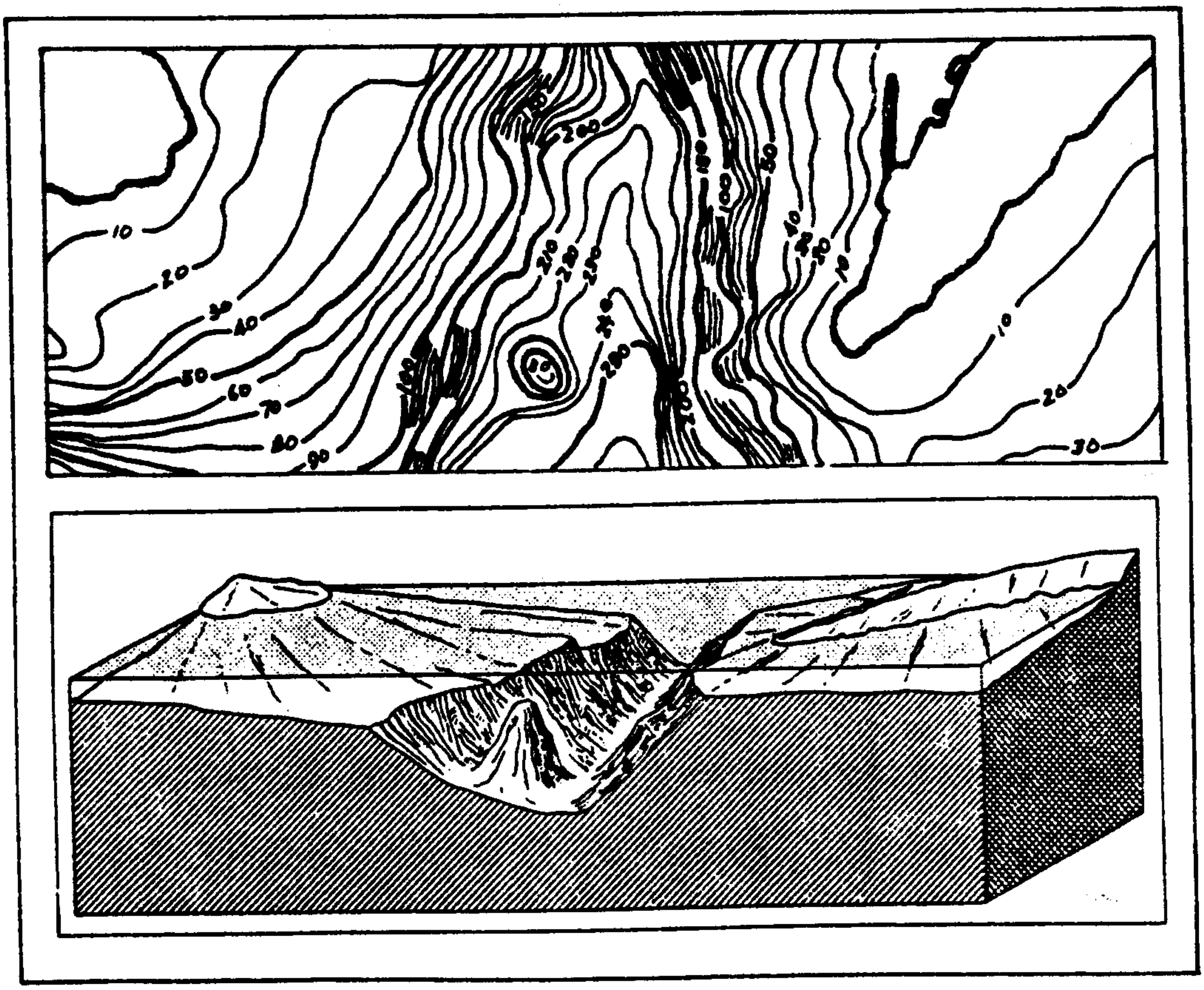
Oceanic Soundings

Soundings. ---Relatively little is known of the surface features of the nearly 71 percent of the earth covered by water. However, enough has

been learned to indicate that the unseen topography beneath the oceans has all the features common to that above water. It is known that there are submerged mountains extending to greater heights above their surroundings than do the Rockies, and depressions deeper than the Grand Canyon.

While many of the general features are known, details are lacking. In any given area, a very large number of accurately located soundings are needed to provide sufficient information for mapping the ocean floor. If sufficient information is available, the relief can be depicted on bathymetric charts by means of contours. A simplified chart of this type is shown in the upper part of the following figure. The lower part of the figure is a back diagram of the area shown on the chart. Only a relatively small part of the oceans has been sounded sufficiently to provide the detailed information needed for such a chart, mainly narrow strips along coasts, i.e., the continental shelves. In theses areas, the soundings have the necessary accuracy and density to portray underwater relief.

As long as oceanic soundings could be made only by a vessel stopping and lowering a weight, a process which might require several hours for a single sounding in very deep water, it was impractical for most vessels to obtain very much depth information at sea. With the development of the echo sounder, however, this situation has changed. With a recording echo sounder, a ship can obtain a profile along its track from continent without slowing, using about a yard of recording paper per day. Such information, if reliable, is of great assistance to charting agencies in preparing more adequate charts of the ocean areas.



Contour lines and hachures (top) may be used to show underwater relief (bottom)

Sounding equipment.—While lead lines and sounding machines have been used at sea, almost all deep-sea soundings are now taken by echo sounder. If a depth recording device is available, it should be used,

as the profile thus produced is a better indication of the bottom than even the most closely spaced visual readings.

All echo sounding equipment is subject to certain errors unless the operator has a clear understanding of the operating characteristics and limitations of the instrument. The routine checks recommended by the manufacturer should be made at every change of the watch, or oftener. In addition, the operator should be alert for certain possible errors peculiar to his instrument. A close watch should be kept on the proper functioning of the stylus, recorder speed, the zero adjustment, and the frequency of the electric current. The percentage error in the recorded depth is the same as that of the electric current frequency. Thus, at 3,000 fathoms, the error of a 60-cycle echo sounder is 100 fathoms if the actual frequency is in error by two cycles.

Evaluating results.—Inaccurate results may be worse than no information at all. Therefore, every effort should be made to obtain reliable data. Particularly, soundings which conflict with known or charted depths should be carefully analyzed. Even when the equipment is operating correctly, false return might be received due to sources external to the vessel. A shoal "phantom bottom" may be due to marine life, there may be multiple echoes or interference, or no return may be received because of aeration of the water or suspended matter in it. Such errors are further discussed in article 3504. Unusual local conditions may be a source of error. If an error is believed probable, but no source is detected, full information should be submitted with the soundings, for the charting agency may be able to interpret the results. This action is particularly important where the measured depths are less than those shown on the chart. If no error can be found, the charting agency may have no alternative but to enter the shoal soundings upon the charts affected, and take the first opportunity to send a survey vessel to verify or disprove them.

The speed at which sound travels in water varies with the salinity, temperature, and pressure. When these are known, corrections can be applied to obtain more accurate results. However, this is normally done only for scientific purposes. Those soundings submitted to a charting

agency should be the uncorrected values obtained by using an assumed standard speed of 4,800 feet or 1,500 meters per second.

Deep sea sounding lines.—Many deep sea soundings are obtained by ships proceeding between ports. Soundings should be taken at every opportunity. Those taken in well-surveyed areas can be assistance to the navigator in locating his position. If they conflict with values shown on the chart, and no error is found, they should be sent to the appropriate charting agency, with full particular. All soundings in areas for which little depth information is shown on the chart should be submitted.

In addition to reliable soundings, accurate positions are needed. Navigation should be in accordance with standard practice, using every practicable means to reduce error and provide frequent checks on position.

When two or more ships are operating together, they should steam on parallel courses about five miles apart. Each ship should collect and record its own navigational data for subsequent submission to the appropriate charting agency.

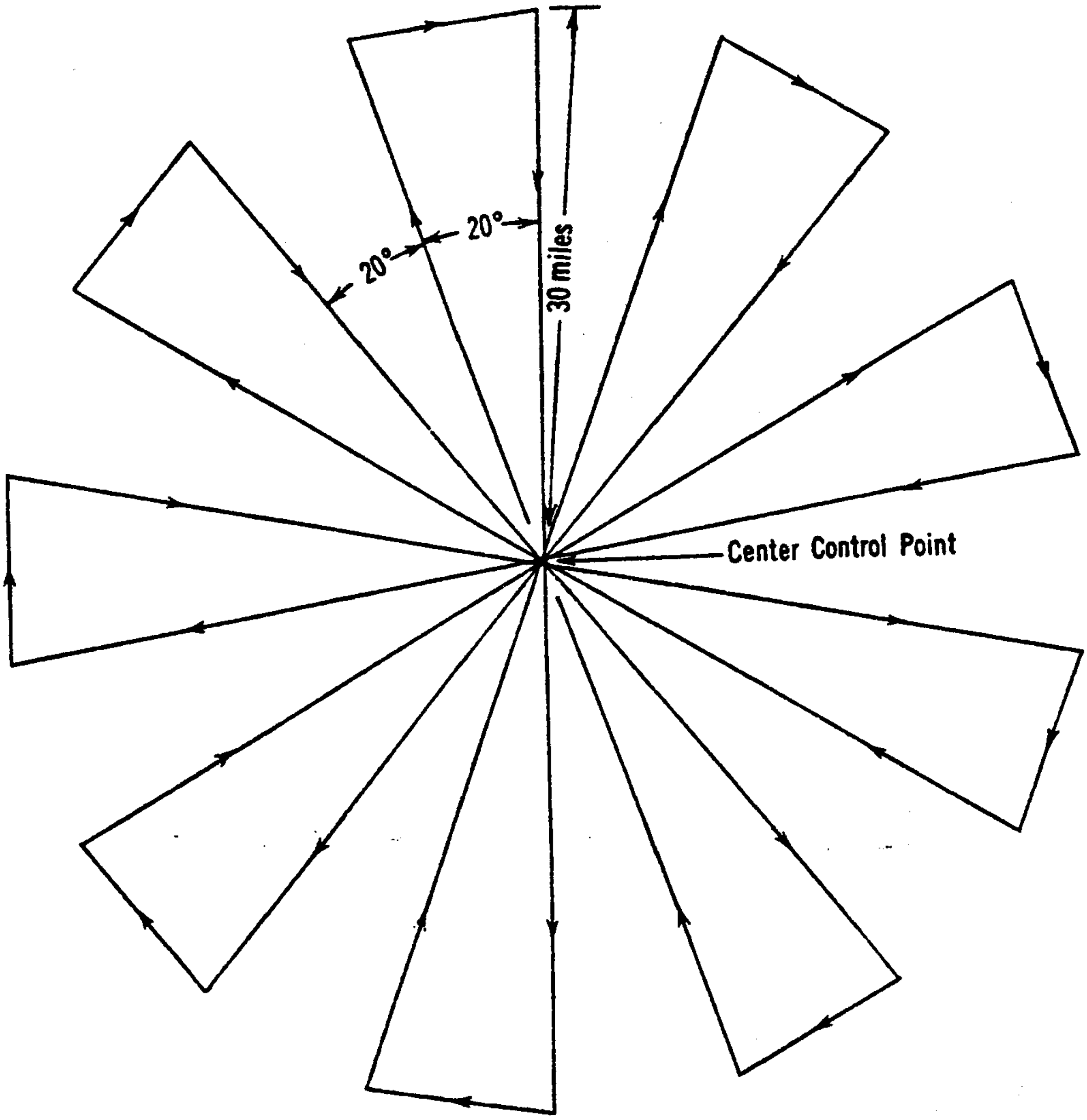
Investigating small areas.—If a feature of particular interest, such as an isolated shoal or a seamount, is found or reported in the vicinity of the vessel, a service can be rendered by conducting a further investigation in the vicinity of the feature. Two methods are in common use for this purpose:

Radial. A system of radial lines 20° apart are laid out from a central control point, preferably at the feature to be investigated. These are extended outward for a distance of about 30 miles, and the ends of alternate ones are connected, as shown in Page 169. These form a series of course lines as shown.

Parallel. A north-south, east-west square is laid out with perhaps 60-mile sides, the center of the feature of interest being at the center of the square. A series of course lines are drawn parallel to one side of the square, at intervals of about 5 miles. The ends of alternative parallel course lines are connected, as shown in Page 171.

During such an investigation, by either method, the best control of position can usually be obtained by anchoring a buoy, if practicable, at

the center of the area. In some instances, several buoys might be used. Any rig having buoyancy adequate to support the necessary length of anchor cable is satisfactory. The type generally used consists of a steel drum or mooring buoy with a weight attached to a cable, in the case of a large buoy, or piano wire if the buoy is small and of insufficient buoyancy to support a cable. A chain is not generally used. Buoys of this type have



Radial course line pattern.

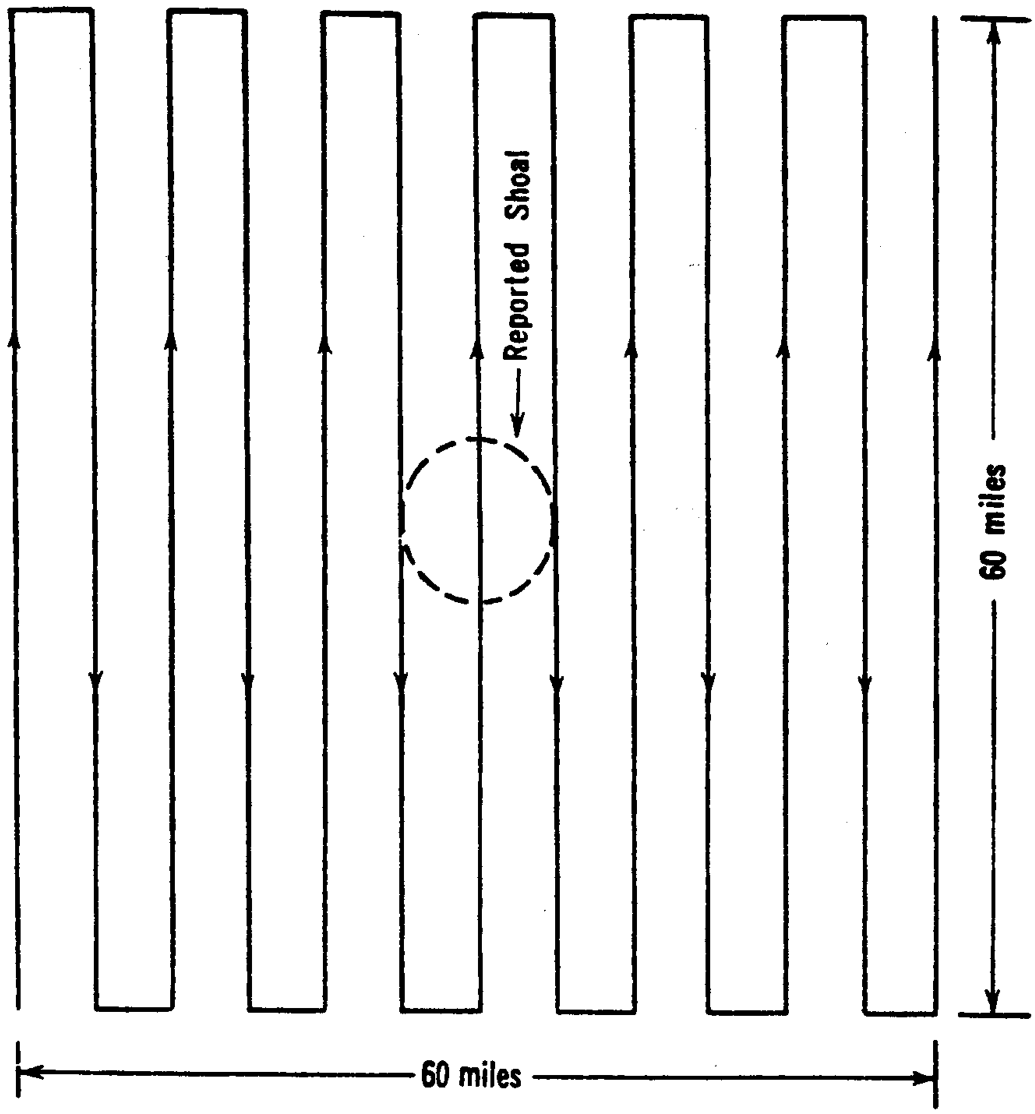
been successfully anchored in depths to 2,500 fathoms. The position of the buoy is determined as accurately as practicable, using celestial navigation, Loran, or whatever means are available. Position of the vessel is determined relative to the buoy or buoys, using visual or radar bearings and ranges at intervals of half an hour or less. Beyond this range, the best available means are used. A balloon with a suspended radar reflector might be attached to the buoy to extend its range of usefulness. The securing line of the balloon should be at least 400 feet long, if practicable.

Sonar ranging, if available, should be used to assist in the location of shoal areas.

Sounding Reports

Records..—Today much of the data processing necessary for compilation of nautical or bathymetric charts is accomplished by computers. Consequently, many of the laborious and time-consuming aspects of sounding report preparation have been eliminated. Computers, if given the proper information, can quickly and efficiently perform all the routine data manipulation tasks formerly done manually by oceanographers and cartographers. However, it is still imperative that the mariner prepare his report accurately and completely, insuring that the basic elements of depth and position, both correlated with time, are included. Described below are the report records that best present these basic elements.

1. **Echograms**. Depth is best depicted by the echogram itself, a continuous analog record that serves not only as a report but also provides verification of the shipboard interpretation. There are many formats for echogram paper, but the essential information needed on an echogram is the following:



Parallel course line pattern.

(i)*Ship Name*. Record at the beginning and end of each roll of echogram or portion thereof.

(ii) *Date*. Annotate at least once each day at 1200 and when starting and stopping echo sounder.

(iii) *Time*. The event marker should be activated and annotated with the correct time at the beginning of the echogram, at least once each watch thereafter, and at the end of the echogram.

(iv) *Time Zones*. Greenwich mean time (GMT) should be used if practicable. In the event local time zones are used, annotate echogram whenever clocks are reset and identify time zone in use. Ambiguity of time zone is the most common cause of difficulty in relating a sounding trace to a ship's position.

(v) *Phase or Scale Changes*. Clearly label all depth phase (or depth scale) changes and the exact time they occur. Annotate the upper and lower limits of echogram if necessary.

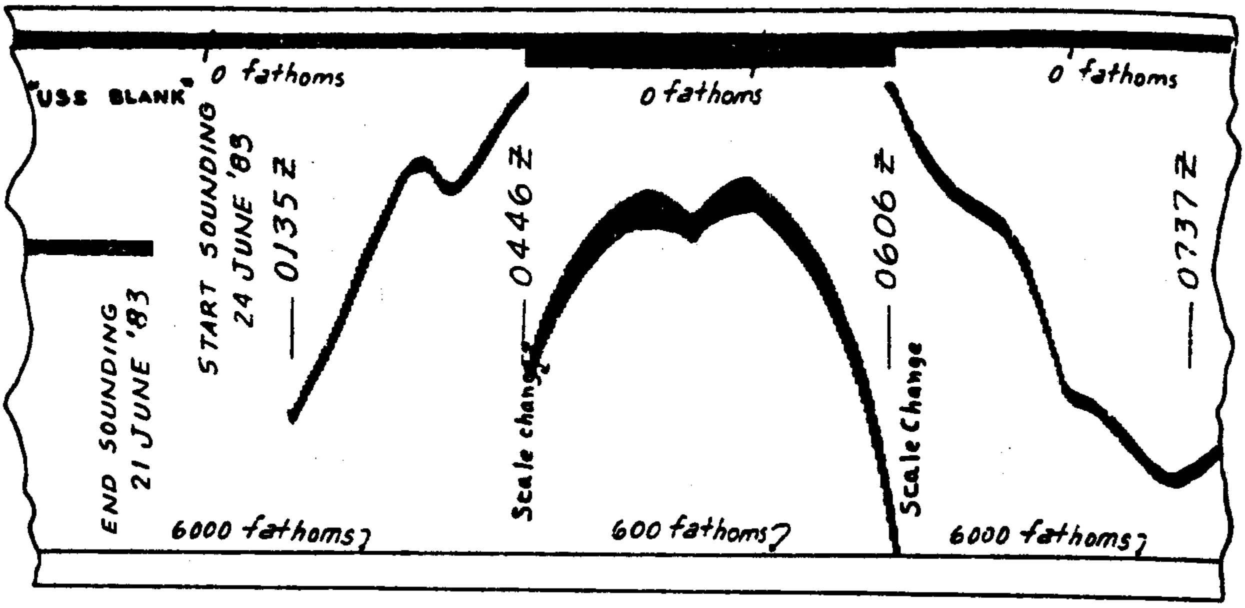
(vi) *Transducer Depth*. The depth of the transducer beneath the surface and whether it is allowed for in the trace is necessary to compute true depth, especially in shoal areas. A specimen echo sounding record is shown in figure 2810a.

2. **Navigation Log**. In the past a smooth plotted track supplemented by the unadjusted plot was an essential part of a sounding report. The computer, with its tremendous capacity for data processing, has relieved the navigator of this monotonous and time-consuming task so that today only the navigation log is necessary. However, it is still important that the navigation log be accurate and contain all of the following information:

(i) Date
(ii) Time (GMT)
(iii) Latitude and longitude
(iv) Type of navigational fix
(v) Course
(vi) Speed
(vii) Remarks

When the above information has been collected and properly annotated, it should be sent to the appropriate charting agency, usually the Defense Mapping Agency Hydrographic/Topographic Center. The commanding officer's or master's forwarding letter should indicate the type of sounding system, any difficulties encountered, and pertinent remarks regarding estimated reliability of the data. Areas where sounding

data are most needed are outlined, *Bathymetric Data Requirements*, which should be inspected prior to a voyage.



Specimen echo sounding record.

NAVIGATION LOG							REMARKS
DATE	TIME (GMT)	LAT.	LONG.	NAV. FIX	COURSE	SPEED	
11/2/83	0221	29°41'N	124°10'E	LORAN	093°	12.3	
	0340				097°	12.3	CHANGE COURSE
	0400	29°40'N	124°35'E	NOON FIX	097°	12.3	
	0728	29°35'N	125°22'E	LORAN	097°	12.3	
	0810				VARIOUS	8.2	REDUCE SPEED - MANUVERING TO AVOID FISHING BOATS
	0826	29°34'N	125°35.5'E	LORAN	097°	12.3	RESUME COURSE AND SPEED
	1011	29°32'N	125°56'E	EVENING STARS	097°	12.3	
	1620	29°23'N	127°22'E	LORAN	102°	12.4	CHANGE COURSE
	2230	29°06.2'N	128°48.5'E	RADAR / STAR	102°	12.5	
	2305				102°	10.1	REDUCE SPEED

Typical navigation log.

Position Reporting Systems

Introduction.—Several thousand merchant vessels are at sea at one time. These vessels have the proven potential for early arrival at a scene of distress. The purpose of a position reporting system is to make possible maximum efficiency in coordinating assistance by merchant vessels at a scene of distress in order to save life and property at sea.

It is important that information be readily available to Search and Rescue (SAR) coordinators immediately upon occurrence of an emergency so that potential assistance can be obtained effectively and with the least delay to offering and needing aid. Establishing communications is sometimes difficult even when automatic alarms are used and determination of **SAR** capabilities and intentions of vessels is time-consuming, unless the essential information has been made readily available beforehand by their participation in a position reporting system.

Regulation 10, chapter V of the *Convention on Safety of Life at Sea* (SOLAS 1960) obligates the master of any vessel at sea who becomes aware of a distress incident to attempt to render assistance. He must proceed and assist until aware that other aid is at hand or until released by the distressed unit. Other international treaties and conventions impose the same requirement. Position reporting systems permit determination of the most appropriate early assistance, provide the means for a timely resolution of distress cases, and enable vessels responding to distress calls to continue their passage with a minimum amount of delay.

Recommendation 47 of IMCO's SOLAS 1960 Conference reads as follows:

"The Conference recommends that Contracting Governments should encourage all ships to report their positions when travelling in areas where arrangements are made to collect these positions for Search and Rescue (SAR) use. Each Government should arrange that such messages shall be free of cost to the ship concerned".

There are currently many position reporting systems in operation throughout the world. The particular of each system are given in publication of the International Maritime Organization (IMO), formerly

known as the Inter-Governmental Maritime Consultative Organization (IMCO).

Masters of vessels making offshore passages are requested by the U.S. Coast Guard to *always* participate in the AMVER System, and to participate in the *other* systems whenever sailing within the areas covered by them.

The Automated Mutual-Assistance Vessel Rescue System (AMVER), operated by the United States Coast Guard, is an international maritime mutual assistance program which provides important aid to the development and coordination of search and rescue (SAR) efforts in many offshore areas of the world. Merchant ships of all nations making offshore passages are encouraged to voluntarily send movement (sailing) reports and periodic position reports to the **AMVER** Center at Coast Guard, New York via selected radio stations. Information from these reports is entered into an electronic computer which generates and maintains dead reckoning for the vessels. Characteristics of vessels which are valuable for determining SAR capability are also entered into the computer from available sources of information.

Information concerning the predicted location and SAR characteristics of each vessel known to be within the area of interest is made available upon request to recognized SAR agencies of any nation or vessels needing assistance. Predicted locations are only disclosed for reasons related to marine safety.

Messages sent within the **AMVER** System are at no cost to the ship or owner. Benefits to shipping include: (1) improved chances of aid in emergencies, (2) reduced number of calls for assistance to vessels not favorably located, and (3) reduced time lost for vessels responding to calls for assistance. An **AMVER** participant is under no greater obligation to render assistance during an emergency than a vessel who is not participating.

All **AMVER** messages should be addressed to coast Guard, New York regardless of the station to which the message is delivered, except those sent to Canadian stations which should be addressed to **AMVER** Halifax or **AMVER** Vancouver to avoid incurring charges to the vessel for theses messages.

In addition to the information calculated from sail plans and position reports, the **AMVER** Center stores data on the characteristics of merchant vessels. This data, reflecting **SAR** capability, includes the following; vessel name; international call sign; nation of registry; owner or operator; type of rig; type of propulsion; gross tonnage; length; normal cruising speed; radio schedule; medium, high, and very high frequency radio facilities; radio facilities; radio telephone installed; surface search radar installed; doctor normally carried. Vessels can assist the **AMVER** Center in keeping this data accurate by sending a complete report by message, letter, or by completing a **SAR** Information Questionnaire (see the following figure) available from **AMVER**, and then sending corrections as the characteristics change. The corrections may easily be included in regular **AMVER** reports as remarks.

For **AMVER** participants bound for U.S. ports there is an additional benefit. **AMVER** participation via messages which include the necessary information is considered to meet the requirements of 33 CFR 161 (Notice of arrival).

AMVER System communications network. – An extensive radio station communications network supports **AMVER** system and provides two routes for assistance messages as well as for **AMVER** messages: coast radio stations and Ocean Station Vessel radio facilities. Propagation conditions, location of vessel, and message density will normally determine which station may be best contacted to establish communications. To insure that no charge is applied, all AMVER messages should be passed through specified radio stations. Those which currently accept **AMVER** messages and apply to coastal station, ship station, or landline charge are listed in each issue of the ***AMVER Bulletin*** together with respective call sign, location, frequency bands, and hours of guard. Although **AMVER** messages may be sent through other stations, the Coast Guard cannot reimburse the sender for any charges applied.

The AMVER Bulletin, published quarterly by Commander, Atlantic Area, United States Coast Guard, Governors Island, New York, 10004, provides information on the operation of the AMVER System of general interest to the mariner. It also provides up-to-date information on the AMVER communications network and Radio Wave Propagation Charts

AUTOMATED MUTUAL-ASSISTANCE VESSEL RESCUE SYSTEM
SEARCH AND RESCUE INFORMATION QUESTIONNAIRE

(Please Print)

NAME OF VESSEL ____________________ CALL SIGN ____________

PREVIOUS NAME OF VESSEL ____________________ PREVIOUS CALL SIGN ____________

MANAGER'S COMPLETE NAME AND ADDRESS: NATION OF REGISTRY ____________

____________________ LENGTH (FEET) ____________

____________________ GROSS TONNAGE ____________

____________________ SERVICE SPEED (KNOTS) ____________

____________________ COASTAL RADIO STATION NORMALLY USED ____________

TYPE OF RIG (Circle One)

A Academic or Training
B Cable
C Cargo, Dry
D Dredge
E Pipe-Layer
F Fishing or Whaling
H Hospital
I Icebreaker
K Car Carrier, RO-RO
L Log, Lumber
N Naval
O Ore, Dry Bulk
P Passenger
R Refrigerated Cargo
S Salvage, Tug or Tender
T Tanker
U LASH
V Van, Container
W Weather Station
X Miscellaneous: Research, Survey, Ferry, etc.

TYPE OF PROPULSION (Circle One)

DE Diesel-Electric
GT Gas Turbine
MV Oil or Gas
NR Nuclear Reactor
SR Steam Reciprocating
ST Steam Turbine
TE Turbo-Electric

COMMUNICATIONS/NAVIGATION EQUIPMENT (Circle All That Apply)

R Surface Radar
T Radiotelephone (2182 kHz)
M INMARSAT
V VHF-FM (156.8 MHz)
X Medium Frequency (405-535 kHz)
Z High Frequency (4000-25110 kHz)
S Single Sideband

MEDICAL CAPABILITIES (Circle All That Apply)

Doctor Normally Carried	YES	NO
Paramedic or Physician's Assistant Normally Carried	YES	NO

RADIO WATCH SCHEDULE (Circle one)

H24 24-Hour Continuous Service
H16 16-Hour Service (ITU Schedule)
H8 8-Hour Service (ITU Schedule)
HX 8-Hour Service (Unspecified Schedule)
N No CW Operation (Radiotelephone Only)

DATE ____________ YOUR NAME AND TITLE ____________________

COMMENTS: ____________________

If you are not on the mailing list of the AMVER quarterly Magazine, the AMVER BULLETIN, and wish to receive it at no cost, please fill in your vessel's mailing address.

SAR Information Questionnaire.

which indicate recommended frequencies for contacting U.S. coast radio stations participating in the AMVER System, according to the time of day and the season of the year.

AMVER participation. ---Instructions guiding participation in the AMVER System are available in the following languages: Chinese, Danish, Dutch, English, French, German, Greek, Italian, Japanese, Korean, Norwegian, Polish, Portuguese, Russian, Spanish and Swedish. The *AMVER Users Manual* is available from: Commander, Atlantic Area, U.S. Coast Guard, Governors Island, N.Y. 10004; Commander Pacific Area, U.S. Coast Guard, Government Island, Alameda, CA 94501; and at U.S. Coast Guard District Offices, Marine Safely Offices, Marine Inspection Offices and Captain of the Port Offices in major U.S. Ports. Requests for instructions should state the language desired if other than English.

Search and Rescue Operation procedures are contained in the *Merchant Ship Search and Rescue Manual (MERSAR)* published by the International Maritime Organization (IMO). U.S. flag vessels may obtain a copy of *MERSAR* from local Coast Guard Marine Safely Offices and Marine Inspection Offices or by writing to U.S. Coast Guard (G-OSR), Washington, DC 20593. Other flag vessels may purchase *MERSAR* directly from IMO.

The coast Guard conducts and/or coordinates search and rescue operations for surface vessels and aircraft that are in distress or overdue.

In connection with a vessel's first AMVER-plotted voyage, the master is requested to complete a questionnaire (fig. 2905) providing the radio watch schedule, available medical and communications facilities, and other useful characteristics. Stored in the AMVER computer, this information can be electronically processed with great speed in an emergency at the same time that a position is calculated.

Any vessel of any nation departing on an offshore passage of 24 hours duration or greater is encouraged to become a participant in the AMVER System by sending appropriate AMVER message in types of formats. The messages may be transmitted at any convenient time as long as the information is accurate and the data corresponds to the time specified. For

example, the information may be estimated for a short time in the future, for the present, or for a short time past.

There are five types of **AMVER** Reports-Sailing Plan, Departure, Arrival, Position, and Deviation Reports.

AMVER participants need to be familiar with the five types of reports. **AMVER** permits sailing plan and departure information to be combined into a single report. **AMVER** accepts sailing plan information separately—for example, several days prior to departure.

Only the above five types of **AMVER** messages require specific formats. (See DMAHTC PUBS. 117A and 117B). Other messages relating to a vessel's **AMVER** participation or data, such as facts on her **SAR** capabilities, may also be sent via the **AMVER** communications network.

Additional information concerning the **AMVER** System may be obtained by writing to Commandant, **U.S.** Coast Guard, Washington, **DC** 20590, or by writing or visiting Commander, Atlantic Area, **U.S.** Coast Guard, Governors Island, New York, NY 10004.

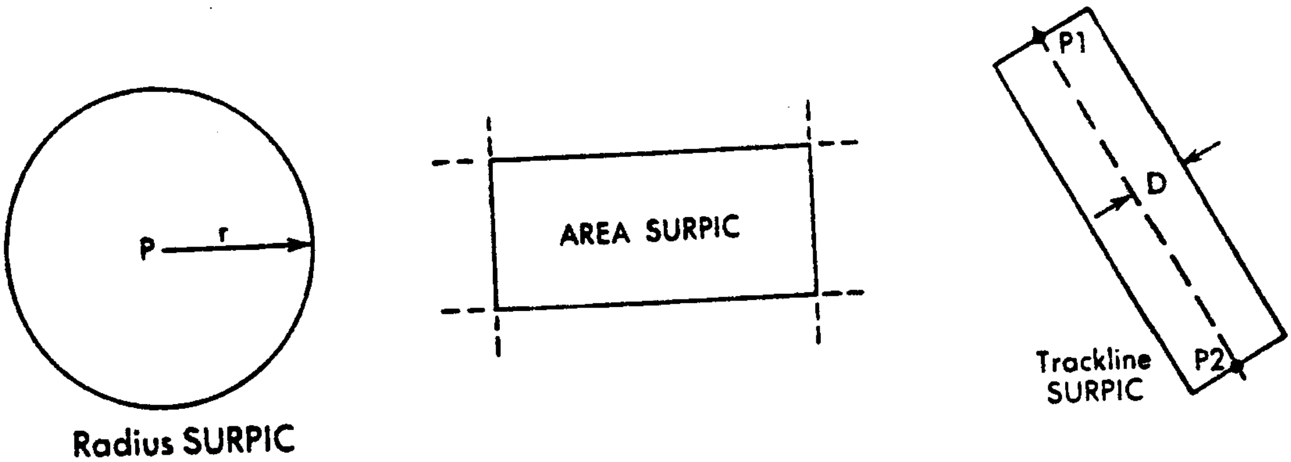
The **AMVER** System is coordinated in the Pacific regions by Commander, Pacific Area, **U.S.** Coast Guard, Government Island, Alameda, CA 94501.

Other countries such as Canada are a formal part of the AMVER System and provide radio stations for relay of AMVER reports as well as coordinating rescue efforts in certain regions. Applicable instructions have been promulgated by official publication of the participating countries.

AMVER Reporting Required.—U.S. Maritime Administration regulations effective August 1, 1983, state that certain U.S. flag vessels and foreign flag "War Risk" vessels must report and regularly update their voyages to the **AMVER** Center. This reporting is required of the following: (a) U.S. flag vessels of 1,000 tons or greater, operating in foreign commerce; (b) foreign flag vessels of 1,000 gross tons or greater, for which an Interim War Risk Insurance Binder has been issued under the provisions of Title **XII**, Merchant Marine Act, 1936.

AMVER plot information.—The information stored in the computer can be used to provide several types of display according to the needs of

controllers at Rescue Coordination Centers. The surface picture (SURPIC) can be displayed as a **Radius SURPIC** (see the following figure). When requesting a Radius **SURPIC**, the controller specific the date and time, a latitude and longitude to mark the center **(P)**, the radius (in nautical miles) that the **SURPIC** should cover **(R)**, whether the names of all ships are desired (or only those with doctors or just those heading either east or west).



Radius SURPIC, AREA SURPIC, and Trackline SURPIC.

A radius **SURPIC** may be requested for any radius from 1 to 999 miles. A sample request is as follows:

"REQUEST 062100Z **RADIUS SURPIC OF DOCTOR-SHIPS WITHIN** 800 **MILES OF** 43.6N 030.2W **FOR MEDICAL EVALUATION M/V SEVEN SEAS"**.

The **AREA SURPIC** (in the above figure) is obtained by the controller specifying the date, time, and two latitudes and two longitudes. The controller can limit the ships to be listed as with the Radius **SURPIC**. The computer responds with a listing of vessels within the boundaries specified.

There is no maximum or minimum size limitation on an **AREA SURPIC**. A sample **AREA SURPIC** request is as follows:

"REQUEST 151300Z AREA SURPIC OF WESTBOUND SHIPS FROM 43N TO 31N LATITUDE AND FROM 130W TO 150W LONFITUDE FOR SHIP DISTRESS M/V EVENING SUN LOCATION 37N, 140W".

The **Trackline SURPIC** (the above figure) is obtained by the controller specifying the date and time, two points (**P-1** and **P-2**), whether the trackline should be rhumb line or great circle, what the half-width (**D**) coverage should be (in miles), and whether all ships are desired (or only doctor ships, or just those east or westbound). The half-width (**D**) specified should not exceed 100 miles. When received, the SURPIC will list ships in order from **P-1** to **P-2**.

There is no maximum or minimum distance between **P-1** and **P-2**.

A sample Trackline **SURPIC** request is as follows:

"REQUEST 310100Z **GREAT CIRCLE TRACKLINE SURPIC OF ALL SHIPS WITHIN** 50 **MILES OF A LINE FROM** 20.1N 150.2W **RO** 21.5N 158.0W **FOR AIRCRAFT PRECAUTION".**

A **Location Vessel** is not a **SURPIC,** AS SUCH. It is used to determine the location of a specific ship. It permits a controller to determine the position of an **AMVER** participant wherever located.

A sample Location Vessel request is as follows:

"REQUEST PRESENT POSITION, COURSE, AND SPEED OF M/V SOLID STATE/HIND".

A Radius **SURPIC** as it would be received by a rescue center, listing all ships within a 200-mile radius of 26.2N, 179.9w, is shown in the following figure.

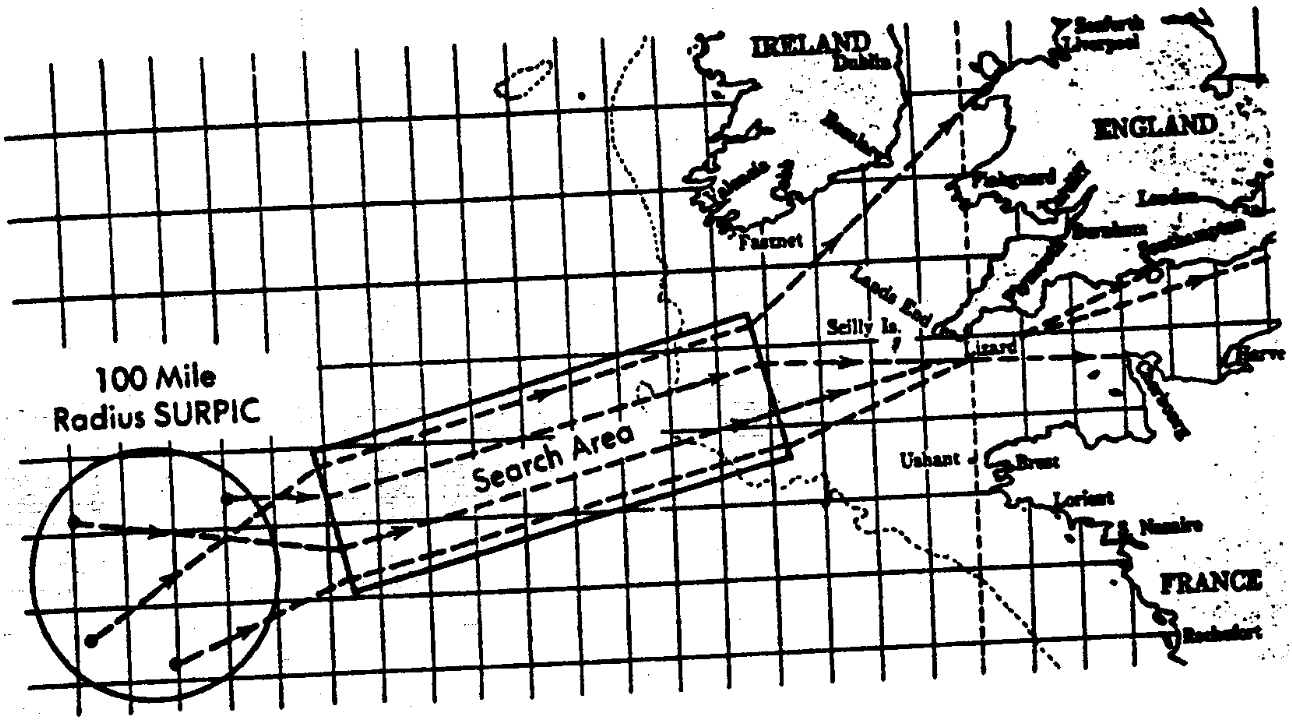
Name	*Call Sign*	*Position*	*Course*	*Speed*	*SAR data*	*Destinatic And ET/*
CHILE MARU	JAYU	26.2N 179.9E	C294	12.5K	H 1 6 R T XZ	KOBE 11
CPA 258 DEG. 012 MI. 032000Z						
WILYAMA	LKBD	24.8N 179.1W	C106	14.0K	H X R T V X Z	BALBOA 2'
CPA 152 DEG.092 MI. 032000Z						
PRES CLEVELAND	WITM	25.5N 177.0W	C284	19.3K	H 2 4 R D T X Z S	YKHAMA 0
CPA WILL PASSWITHIN 10MI 040430Z						
AENEAS	GMRT	25.9N 176.9E	C285	16.0K	H 8 R N V X Z	YKHAMA 1
CPA 265 DEG. 175 MI. 03200Z						

Radius SURPIC as received by a rescue center.

Uses of AMVER plot information.—An example of the use of a Radius **SURPIC** is depicted in the following figure. In this situation rescue authorities believe that a ship in distress, or her survivors, will be found in the rectangular area. The Rescue Coordination Center requests a listing of all eastbound ships within 100 miles of a carefully chosen position. Once this list is received by the Rescue Coordination Center a few moments later, the names and call letters of those ships chosen to assist in the search can be passed to a powerful commercial radio station nearby for inclusion in their next regularly scheduled **TRAFFIC LISTS** (normally broadcast every 2 hours). These ships will be notified that rescue authorities are waiting to contact them on a given working frequency.

Each ship contacted may be asked to sail a rhumb line between two specified points, one at the beginning of the search area and one at the end. By carefully assigning ships to areas of needed coverage, very little time need be lost from the sailing schedule of each cooperating ship. Those ships joining the search would report their positions every few hours to the Rescue Coordination Center, together with weather data and any significant sightings. In order to achieve saturation coverage, a westbound **SURPIC** at the eastern extremity of the search area would be used.

The Trackline **SURPIC** is most commonly used as a precautionary measure for aircraft. Rarely, if ever, is a major airliner forced to ditch at sea anymore. But occasions frequently arise where a plane loses the



Use of Radius SURPIC

services of one or more of its engines. A Trackline **SURPIC** provided from the point of difficulty to the destination provides the pilot with the added assurance of knowing the positions of vessels beneath him. **SURPIC's** have been used successfully to save the lives of pilots of small aircraft.

CHAPTER V

VISUAL AND AUDIBLE AIDS TO NAVIGATION

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VISUAL AND AUDIBLE AIDS TO NAVIGATION

Introduction. – The term **aid to navigation**, as used herein, means any device external to a vessel intended to be of assistance to a navigator in his determination of position or safe course, or to provide him with a warning to dangers or obstructions to navigation. This term includes lighthouses, beacons, sound signals, buoys, marine radiobeacons, racons, and the medium and long range radio navigation systems. The discussion of the various aids to navigation in this chapter is limited to the visual and audible aids established in the navigable waters of the United States and its possessions.

Aids to navigation are placed at various points along the cost and navigable waterways as markers and guides to mark safe water and to provide navigators with means to determine their position with relation to the land and to hidden dangers. Within the bounds of actual necessity, each aid is designed to be seen or heard so that it provides the necessary system coverage to enable safe transit of a waterway.

As all aids to navigation serve the same general purpose, structural differences are solely for the purpose of meeting the conditions and requirements of the particular location at which the aid is established.

The maintenance of marine aids to navigation is a function of the United States Coast Guard. This responsibility includes the maintenance of lighthouses, radiobeacons, racons, Loran, sound signals, buoys, and beacons upon all navigable waters of the United States and its possessions, including the Atlantic and Pacific coasts of the continental United States, the Great Lakes, the Mississippi River and its tributaries, Puerto Rico, the U.S. Virgin Islands, the Hawaiian Islands, Alaska, Trust Territory of the Pacific Islands, and such other places where aids to navigation are required to serve the needs of the armed forces.

Lights on Fixed Structure

Lights on fixed structures vary from the tallest lighthouse on the coast, flashing with an intensity of million of candlepower, to a simple battery-powered lantern on a wooden pile in a small creek. Being in fixed positions enabling accurate charting lights provide navigators with reliable means to determine their positions with relation to land and hidden dangers during daylight and darkness. The structures are often distinctively colored to facilitate their observation during daylight.

A major light is a light of high intensity and reliability exhibited from a fixed structure or on a marine site (except range lights). Major lights include primary seacoast lights and secondary lights. **Primary seacoast lights** are those major lights established for the purpose of making landfalls and coastwise passages from headland to headland. **Secondary lights** are those major lights, other than primary seacoast lights, established at harbor entrances and other locations where high intensity and reliability are required. Major lights are usually located at manned or monitored automated stations.

A minor light is an automatic unmanned (unwatched) light on a fixed structure showing usually low to moderate intensity. Minor lights are established in harbors, along channels, rivers, and isolated locations. They usually have the same numbering, coloring, and light and sound characteristics as the lateral system of buoyage.

Lighthouses (Page 188), all of which exhibit major lights, are placed where they will be of most use: on prominent headlands, at entrances, on isolated dangers, or at other points where it is necessary that mariners be warned or guided. Their principal purpose is to support a light at a considerable height above the water. In many instances, sound signals, radiobeacon equipment, and operating personal are housed in separate building located near the tower. Such a group of facilities is called a **light station**.

Many of the lighthouses which were originally tended by resident keepers are now operated automatically. There are also many automatic lights on smaller structures maintained through periodic visits of Coast Guard cutters or of attendants in charge of a group of such aids. The introduction of new automatic apparatus means that the relative

importance of lights cannot be judged on the basis of whether or not they have resident keepers.

Offshore light stations and large navigational buoys have replaced lightships. The offshore light stations in U.S. waters, such as the one shown in (Page 198) have helicopter landing surfaces. In the 1983 *Light List*, the CHESAPEAKE LIGHT station is described as a blue tower on a white square superstructure on four black piles. "CHESAPEAKE" is on sides; the piles are floodlighted sunset to sunrise.

Range lights (Page 190) are pairs of lights so located as to form a range in line with the center of channels or entrance to a harbor. The rear light is higher than the front light and a considerable distance in back of it, thus enabling the mariner to use the range by keeping the lights in line as he progresses up the channel. Range lights are sometimes used during daylight hours through the use of high intensity lights. Otherwise, the range light structure are equipped with daymarks for ordinary daytime use.

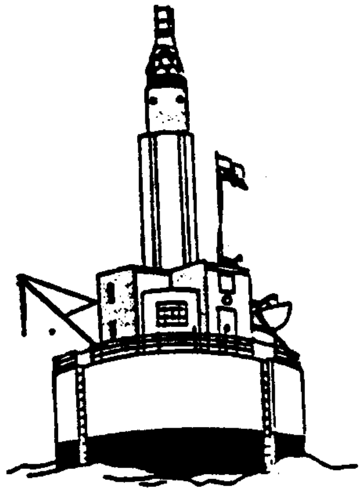
Range lights are usually white, red, or green, and display various characteristics to differentiate them from surrounding lights.

A directional light is a single light which projects a beam of high intensity, separates color, or special characteristic in a given direction. It has limited use for those cases where a two-light range may not be practicable or necessary, and for special applications. The directional light is essentially a narrow sector light with or without adjacent sectors which give information as to the direction of and relative displacement from the narrow sector.

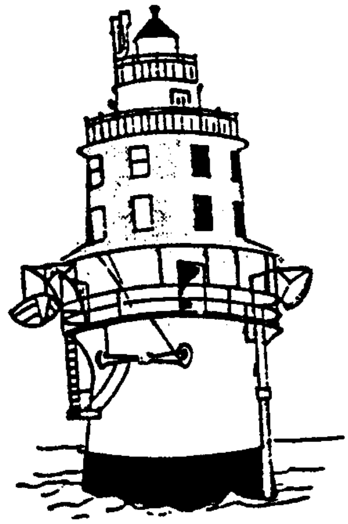
Aeronautical lights, which are lights of high intensity, may be the first lights observed at night from vessels approaching the coast. Those situated near the coast are accordingly listed in the *List of Lights* in order that the navigator may be able to obtain more complete information concerning their description. These lights are not listed in the U.S. Coast Guard *Light List*.

Aeronautical lights are placed in geographic sequence in the body of the text of the *List of Lights* along with lights for marine navigation. It should be borne in mind, however, that these lights are not designed or

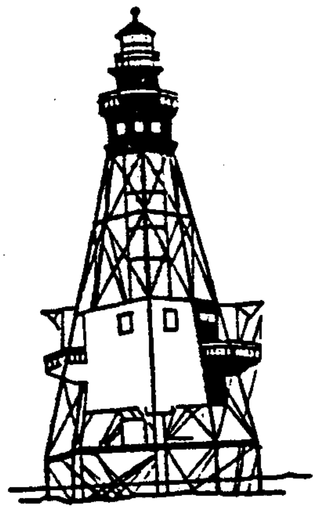
MASONRY STRUCTURE



CYLINDRICAL TOWER SQUARE HOUSE ON CYLINDRICAL BASE

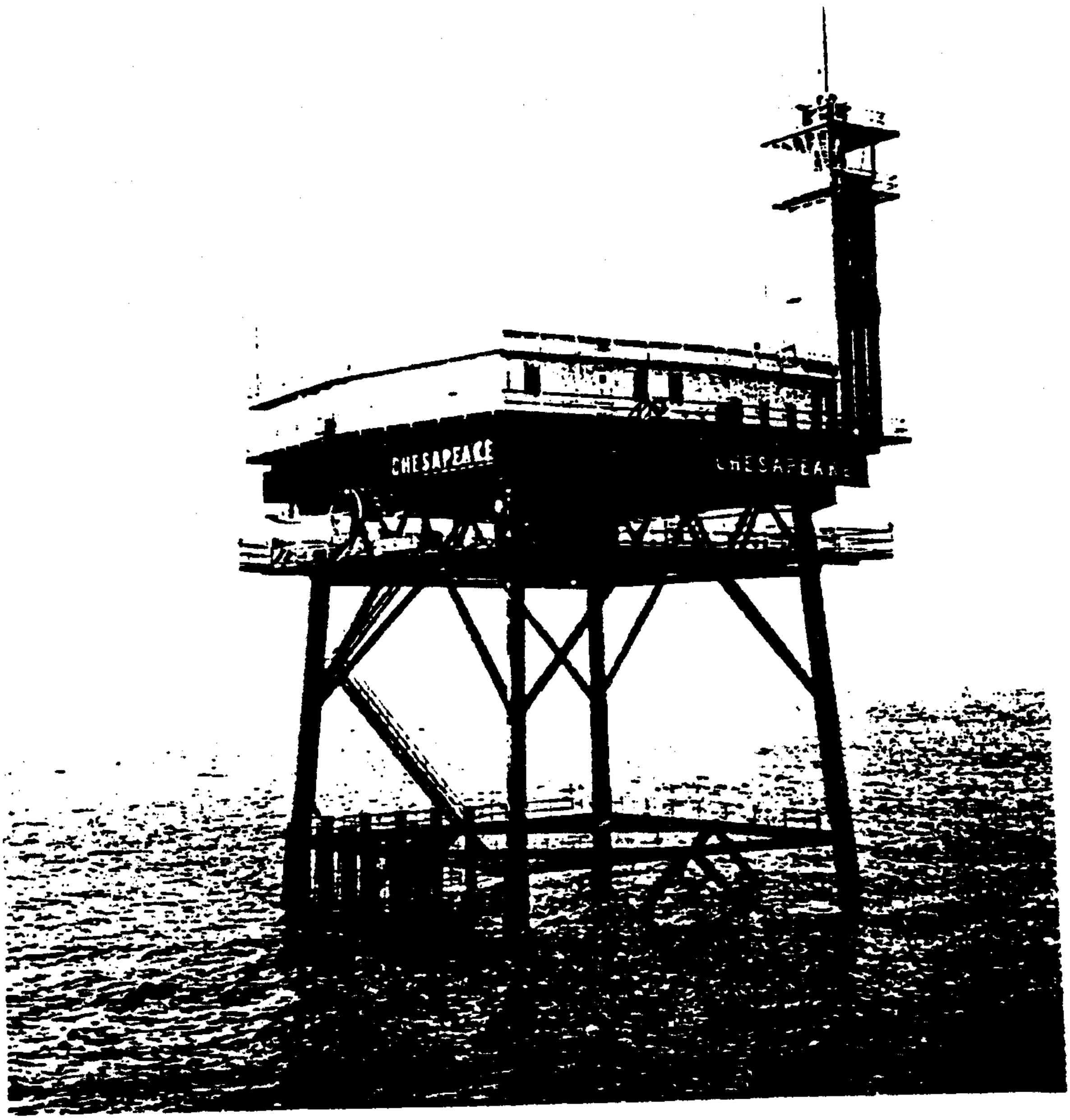


CYLINDRICAL CAISSON STRUCTURE



SKELETON IRON STRUCTURE

Typical light' structures.

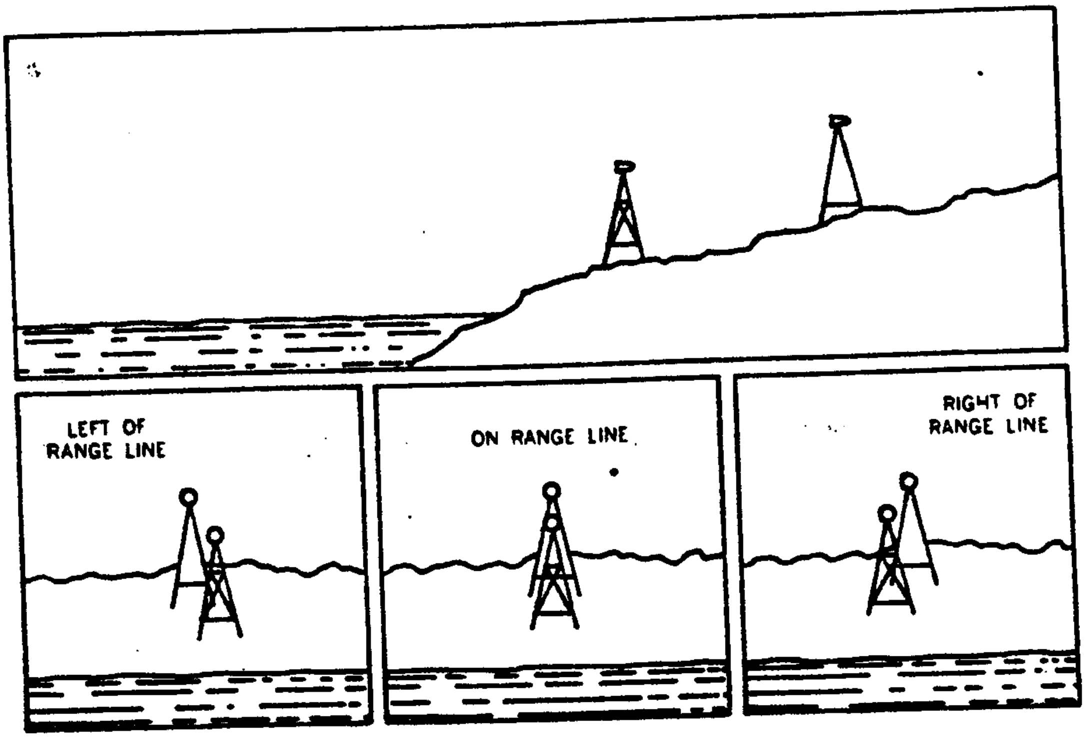


Typical offshore light station.

maintained for marine navigation, and that they are *subject to changes of which neither lighthouse authorities nor the marine navigator may receive prompt notification.*

Bridges across navigable waters of the United States are generally marked with red, green, and white lights for nighttime navigation. Red lights mark piers and other parts of the bridge. Red lights are also used on drawbridges to show when they are in the closed Green lights are used to mark the centerline of navigable channels through fixed bridges. The preferred channel, if there are two or more channels through the bridge, is marked by three white lights in a vertical line above the green light.

Green lights are also used on drawbridges to show when they are in the open position. Because of the variety of drawbridges, the position of the green lights on the bridge will vary according to the type of structure. Navigational lights on bridges are prescribed by regulation.



Range lights.

Bridge infrequently used may be unlighted. In unusual cases the type and method of lighting may be different than normally found.

Drawbridges required to be operated for passage of vessels operate upon sound and light signals given by the vessel and acknowledged by the bridge. These signals are prescribed by regulation.

In addition to lighting, certain bridges may be equipped with sound signals and radar reflectors where unusual geographic or weather conditions require them.

Lights Characteristics

Characteristics. – Lights are given distinctive characteristics so that one light may be distinguished from another navigational light or from the general background of shore lights or as a means of conveying certain definite information. This distinctiveness may be obtained by giving each light a distinctive sequence of light and dark intervals, having lights that burn steadily and others that flash or occult, or by giving each light a distinctive color, or color sequence. In the light lists, the dark intervals are referred to as **eclipses**. An **occulting light** is a light totally eclipsed at regular intervals, the duration of light always being greater than the duration of darkness. A **flashing light** is a light which flashes at regular intervals, the duration of light always being less than the duration of darkness. An **equal interval light** is a light which flashes at regular intervals, the duration of light always being equal to the duration of darkness. This light is also called an **isophase light**.

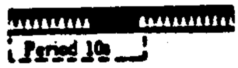
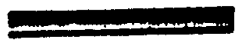
Light phase characteristics (see the following figures) are the distinctive sequences of light and dark intervals or distinctive sequences in the variations of the luminous intensity of a light. The light phase characteristics of lights which change color do not differ from those of lights which do not change color. A light showing different colors alternately is described as an **alternating light**. The alternating characteristic may be used with other light phase characteristics.

CHARACTERS OF LIGHTS

CLASS	ABBREVIATION	GENERAL DESCRIPTION	ILLUSTRATION
Fixed light	F	A continuous and steady light.	
Occulting light	Oc, Occ	The total duration of light in a period is longer than the total duration of darkness and the intervals of darkness (eclipses) are usually of equal duration. Eclipse regularly repeated.	
Group-occulting light	Oc (2), Gp Occ (2)	An occulting light in which a group of eclipses, specified in number, is regularly repeated.	
Composite group-occulting light	Oc (2 + 1), Gp Occ (2 + 1)	A light similar to a group-occulting light except that successive groups in a period have different numbers of eclipses.	
Isophase light	Iso	A light in which all the durations of light and darkness are clearly equal.	
Flashing light	Fl	A light in which the total duration of light in a period is shorter than the total duration of darkness and the appearances of light (flashes) are usually of equal duration (at a rate of less than 50 flashes per minute).	
Long-flashing light	L Fl	A single-flashing light in which an appearance of light of not less than 2 sec. duration (long flash) is regularly repeated.	
Group-flashing light	Fl (3), Gp Fl (3)	A flashing light in which a group of flashes, specified in number, is regularly repeated.	
Composite group-flashing light	Fl (2 + 1), Gp Fl (2 + 1)	A light similar to a group-flashing light except that successive groups in a period have different numbers of flashes.	
Quick light	Q, Qk Fl	A light in which a flash is regularly repeated. Flashes are repeated at a rate of not less than 50 flashes per minute but less than 80 flashes per minute.	
Group quick light	Q (3), Gp Fl (3)	A light in which a specified group of flashes is regularly repeated. Flashes are repeated at a rate of not less than 50 flashes per minute but less than 80 flashes per minute.	
	Q (9), Gp Fl (9)		
	Q (6) + LFl, Gp Fl (6)		

Light phase characteristics.

CHARACTERS OF LIGHTS

CLASS	ABBREVIATION	GENERAL DESCRIPTION	ILLUSTRATION
Interrupted quick light	IQ, Int Qk Fl	A light in which the sequence of quick flashes is interrupted by regularly repeated eclipses of constant and long duration.	
Continuous very quick light	VQ, Qk Fl	A very quick light in which a flash is regularly repeated. Flashes are repeated at a rate of not less than 80 flashes per minute but less than 160 flashes per minute.	
Group very quick light	VQ (3), Gp Fl (3)	A very quick light in which a specified group of flashes is regularly repeated.	
	VQ (9), Gp Fl (9)		
	VQ (6) + LFl, Gp Fl 6 + LFl		
Interrupted very quick light	IVQ, Int Qk Fl	A light in which the sequence of quick flashes is interrupted by regularly repeated eclipses of constant and long duration.	
Continuous ultra quick light	UQ, Qk Fl	An ultra quick light in which a flash is regularly repeated. Flashes are repeated at a rate of not less than 160 flashes per minute.	
Interrupted ultra quick light	IUQ	An ultra quick light in which the sequence of flashes is interrupted by eclipses of long duration.	
Morse code light	Mo (U)	A light in which appearances of light of two clearly different durations are grouped to represent a character or characters in the Morse Code.	
Fixed and flashing light	FFl	A light in which a fixed light is combined with a flashing light of higher luminous intensity.	
Alternating light	Al, Alt	A light showing different colors alternately.	

NOTES: 1. Alternating lights may be used in combined form with most of the previous classes of lights. 2. The second abbreviation shown for a light, if any, is alternate U.S. usage and is being superseded as new editions of charts are produced.

Light phase characteristics.

With each 90° period the light is first fixed white for 59^s, then fixed red for 14^s, then there is a flash of white for 3^s, and finally the light is fixed for 14^s.

A Light List entry for a group flashing light may be given as:

F1. (2) W., 15^s
0.2^s fl., 30^s ec.
0.2^s fl., 11.6^s ec.
(2 falshes).

Within each 15^s period, there is first a white flash of $0^s.2$ duration, the light is eclipsed (extinguished) for 3^s, then there is a white flash of $0^s.2$ duration, and then the light is eclipsed for $11^s.6$ before the sequence begins again.

A Light List entry for a composite group flashing light may be given as:

F1. (1+2) W., 15^s
0.2^s fl., 5.8^s ec.
0.2^s fl., 2.8^s ec.
(3 flashes).

Within each 15^s period, there is first a white flash of $0^s.2$ duration, the light is eclipsed for $5^s.8$, then there is a white flash of $0^s.2$ duration, the light is eclipsed for $2^s.8$, and then there is a $0^s.2$ duration white flash followed by a $5^s.8$ eclipse. Thus, the first group consists of a single flash; the second group consists of two flashes. This is indicated by the (1+2) notation.

Most lighted aids to navigation are automatically extinguished during daylight hours by switches activated by daylight. These switches are not of equal sensitivity. Therefore, all lights do not come on or go off at the same time. Mariners should take this fact into account when identifying aids to navigation during twilight periods when some lighted aids are on while others are not.

Sectors or colored glass or plastic are placed in the lanterns of certain lights to mark shoals or to warn mariners off the nearby land. Lights so equipped show one color from most directions and a different color or colors over definite arcs of the horizon as indicated in the light lists and upon the charts. A sector changes the color of a light, when viewed from

certain directions, but not the characteristic. For example, a flashing white light having a red sector, when viewed from within the sector, will appear flashing red.

Sectors may be but a few degrees in width, marking an isolated rock or shoal, or of such width as to extend from the direction of the deep water toward shore. Bearings referring to sectors are expressed in degrees as observed from a vessel toward the light.

In the majority of cases, water areas covered by red sectors should be avoided, the exact extent of the danger being determined from an examination of the charts. In some cases a narrow sector may mark the best water across a shoal. A narrow sector may also mark a turning point in a channel.

The transition from one color to the other is not abrupt, but changes through an arc of uncertainty of about 2° or less, which depends upon the optical design of the components of the lighting apparatus.

Factors affecting visual range and apparent characteristics.—The condition of the atmosphere has a considerable effect upon the distance at which lights can be seen. Sometimes lights are obscured by fog, haze, dust, smoke, or precipitation which may be present at the light or between it and the observer, but not at the observer and possibly unknown to him. On the other hand, refraction may often cause a light to be seen farther than under ordinary circumstances. A light of low intensity will be easily obscured by unfavorable conditions of the atmosphere and less dependence can be placed on its being seen. For this reason, the intensity of a light should always be considered when expecting to sight it in thick weather. Haze and distance may reduce the apparent duration of the flash of a flashing light. In some conditions of the atmosphere white lights may have a reddish hue. In clear weather green lights may have a whitish hue.

It should be remembered that lights placed at great elevations are more frequently obscured by clouds, mist, and fog than those near sea level.

In regions where ice conditions prevail in the winter, the lantern panes of unattended lights may become covered with ice or snow, which will greatly reduce the luminous ranges of the lights and may also cause lights to appear of different color.

The increasing use of brilliant shore lights for advertising, illuminating bridges, and other purposes, may cause navigational lights, particularly those in densely inhabited areas, to be outshone and difficult to distinguish from the background lighting. Mariners are requested by the U.S. Coast Guard to report such cases as outlined above in order that steps may be taken to attempt to improve the conditions.

The "loom" of a powerful light is often seen beyond the geographic range of the light. The loom may sometimes appear sufficiently sharp to obtain a bearing.

At short distances, some of the *brighter* flashing lights may show a faint continuous light between flashes.

It should be born in mind that, when attempting to sight a light at night, the geographic range is considerably increased from aloft. By noting a star immediately over the light an accurate compass bearing may be indirectly obtained on the light from the navigating bridge although the light is not yet visible from that level.

The distance of an observer from a light cannot be estimated by its apparent intensity. *Always check the characteristics of lights* in order that powerful lights visible in the distance shall not be mistaken for nearby lights showing similar characteristics at lower intensity (such as those on lighted buoys).

If lights are not sighted within a reasonable time after prediction, a dangerous situation may exist requiring prompt resolution or action to insure the safety of the vessel.

The apparent characteristics of a complex light may change the distance of the observer. For example, a light which actually displays a characteristic of fixed white varied by flashes of alternating white and red (the phases having a decreasing range of detection in the order: flashing white, flashing white, flashing red, fixed white) may, when first sighted in clear weather, show as a simple flashing white light. As the vessel draws nearer, the red flash will become visible and the characteristic will apparently be alternating flashing white and red. Later, the fixed white light will be seen between the flashes and the true characteristic of the light finally recognized—Fixed white, alternating flashing white and red (F.W.Alt.Fl. W. and R.).

There is always the possibility of a light being extinguished. In the case of unattended lights, this condition might not be immediately detected and corrected. The mariner should immediately report this condition. During periods of armed conflict, certain lights may be deliberately extinguished without notice if the situation warrants such action.

Large Navigational Buoys

Large navigational buoys and offshore light stations have replaced lightships. These 40-foot diameter buoys (the following figure) may show secondary lights from heights of about 36 feet above the water. In addition to the light, these buoys may mount a radiobeacon and provide sound signals. A station buoy may be moored nearby.

Station buoys, often called **watch buoys,** are sometimes moored near navigational buoys to mark the approximate station should the buoy be carried away or temporarily removed. Since these buoys are always unlighted and, in some cases, moored as much as a mile from the navigational buoys, the danger of a closely passing vessel colliding with them is always present—Particularly so during darkness or periods of reduced visibility.

Experience shows that offshore light stations cannot be safely used as leading marks to be passed close abroad, but should always be left broad off the course, whenever searoom permits.

Large navigational buoy.

Buoyage and Beaconage

Buoys are used to delineate channels, indicate shoals, mark obstructions, and warn the mariner of dangers where the use of fixed aids for such purposes would be uneconomical or impracticable. By their color, shape, number, and light or sound characteristics, buoys provide indications to the mariner as to how he may avoid navigational hazards.

There are many different sizes and types of buoys to meet the wide range of environmental conditions and user requirements. The principle types of buoys used by the United States are lighted, lighted sound, unlighted sound, and unlighted. Some examples of these types are illustrated in Chart No. 1.

A lighted buoy consists of a floating hull with a tower on which a lantern is mounted. Batteries to power the light are contained in special pockets in the buoy hull. To keep the buoy in an upright stable position a large counterweight (Page 201) sometimes is extended from a tube attached to the base of the hull below the water surface. The radar reflector , on those buoys so equipped, forms a part of the buoys tower.

Lighted sound buoys have the same general configuration as lighted buoys but are equipped with either a gong, bell, whistle, or electronic horn. Bells and gongs on buoys are sounded by tappers that hang from the tower and swing as the buoys roll in the sea. Bell buoys produce sound of only one tone; gong buoys produce several tones.

Whistle buoys make a loud moaning sound caused by the rising and falling motions of the buoy in the sea. A sound buoy equipped with an electronic horn will produce a pure tone at regular intervals and will operate continually regardless of the sea state.

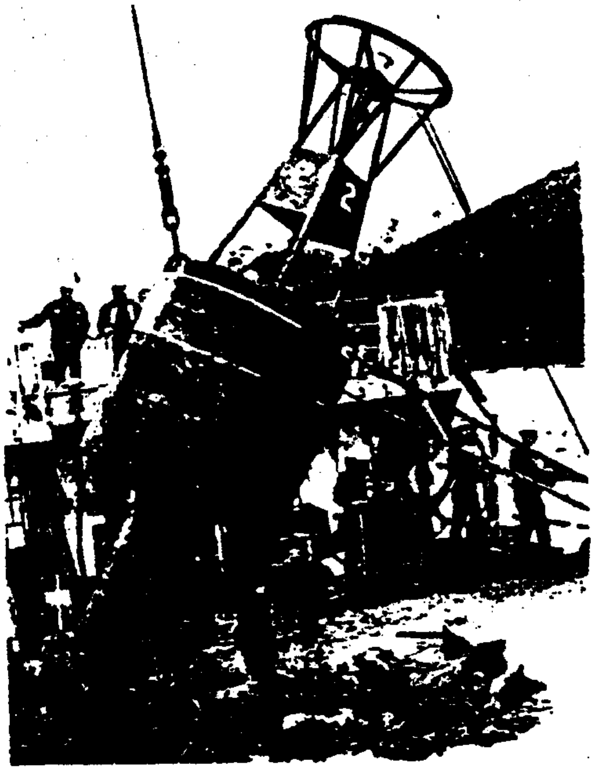
Unlighted sound buoys have the same general appearance as lighted buoys (except for old whistle buoys) but are equipped with any apparatus.

Unlighted buoys have either a can or nun shape. Can buoys have a cylindrical shape whereas **nun buoys** have a conical shape usually located on top of a cylindrical shape. Since these buoys are unlighted there is no requirement for battery pockets, and the hull of the buoy forms part of the shape.

Buoys are *floating aids* and therefore require moorings to hold them in position. Typically the mooring consists of chain and a large concrete sinker (Page 201). Because buoys are subjected to waves, wind, tides, and other conditions, the moorings must be deployed in lengths greater than the water depth. The scope of chain can be as much as 5 times the depth of water or more but normally will be about 3 times the water depth. For this reason the buoy can be expected to swing in a circle as the current, wind, and wave conditions change.

Fallibility of buoys.—It is *imprudent* for a navigator to rely on floating aids to navigation to always maintain their charted positions and to constantly and unerringly display their advertised characteristics.

The buoy symbol shown on charts indicates the approximate position of the buoy body and the sinker which secures the buoy to the seabed. The approximate position is used because of practical limitations in placing and keeping buoys and their sinkers in exact geographical locations. These limitations include, but are not limited to, inherent inaccuracies in position fixing methods, prevailing atmospheric and sea conditions, the slope of and the material making



Buoys showing counterweight

Sinkers used to anchor buoys

up the seabed, the fact that buoys are moored to sinkers with more chain than the water depth, and the fact that the position of the buoys and the sinkers are not under continuous surveillance but are normally checked only during periodic maintenance visits which often occur more than a year apart. The position of the buoy can be expected to shift inside and outside the area shown by the chart symbol due to the forces of nature. The mariner is also cautioned that buoys are liable to be missing, shifted, overturned, etc. Lighted buoys may be extinguished or sound signals may not function because of ice, running ice, natural causes, collisions, or other accidents.

For these reasons, a prudent mariner must not rely completely upon the position or operation of buoys, but will also navigate using bearing of

charted features, structures, and aids to navigation on shore. Further, a vessel attempting to pass to close always risks a collision with a yawing buoy or with the obstruction which the buoy marks.

The concept that a wreck buoy always occupies a position directly over the wreck it is intended to mark is erroneous. Buoys must be placed in position by a vessel. It is usually physically impossible for these vessels to maneuver directly over a wreck to place the sinker without incurring serious underwater damage. For this reason, a wreck buoy is usually placed on the seaward or channel ward side of a wreck, the proximity there to being governed by existing conditions. To avoid confusion in some situations, two buoys may be used to mark the wreck. Both may not be located on the seaward or channelward side of the wreck, but the wreck, but the wreck will lie between them. Obviously, the mariner should not attempt to pass between buoys so placed.

Sunken wrecks are not always static. They are sometimes moved away from their buoys by severe sea conditions or other causes. Just as shoals may shift away from the buoys placed to mark them, wrecks may shift away from wreck buoys.

All buoys should, therefore, be regarded as warnings, guides, or aids but not as infallible navigation marks, especially those located in exposed positions. whenever possible, a mariner should navigate by bearings or angles of reliable and identifiable fixed charted features or landmarks and by soundings rather than by sole reliance on buoys.

Buoyage Systems.—The International Association of Lighthouse Authorities **(LALA)** Maritime Buoyage System (combined cardinal and lateral) is being implemented by nearly every maritime jurisdiction in the world as either Region A buoyage (red to port) or Region B buoyage (red to starboard). For a description of Region A and Region B buoyage systems and an illustration showing an outline of the regions see appendix Y.

Conversion in Region A began in 1977 and will continue until 1987 and possibly later. Conversion in Region B, which includes North, Central, and south America, Japan, South Korea and the Philippines has begun (1983) and it can be anticipated that several years will be required to complete its transformation.

In 1982, the United States agreed to make *modifications* to incorporate that LALA Maritime Buoyage System for Region B. The Modified U.S. Aid System is described below. The U.S. lateral system is not materially changed.

In the lateral system, used on all navigable waters of the United States, the coloring, shape, numbering, and lighting of buoys indicate the direction to a danger relative to the course which should be followed. The color, shape, lights, and numbers of buoys in the lateral system as used by the United States are determined relative to a direction *from* seaward. Along the *coasts* of the United States, the *clockwise* direction around the country is arbitrarily considered to be the direction "from seaward". Proceeding in a westerly and northerly direction on the Great Lakes (except Lake Michigan), and in a southerly direction on Lake Michigan, is proceeding " from seaward". On the Intracoastal Waterway proceeding in a general southerly direction along the Atlantic coast, and in a general westerly direction along the Gulf coast, is considered as proceeding "from seaward". On the Mississippi and Ohio Rivers and their tributaries the aids to navigation characteristics are determined as proceeding from sea toward the head of navigation although local terminology describes " left bank" and " right bank" as proceeding with the flow of the river. Some countries using the lateral system have methods of coloring their buoys and lights opposite to that of the United States. Appendix Y treats this subject in greater detail.

Modified U.S. Aid System

The description that follows is that of the new Modified U.S. aids to Navigation System. Significant changes include: black lateral buoys to be made green; red and black horizontally banded preferred channel buoys to be made red and green horizontally banded; white lights to be replaced by lateral colors (red or green) on lateral aids; black and white vertically striped mid-channel aids to made red and white vertically striped; special purpose and other non-lateral aids to be made yellow, those which are lighted are to be fitted with yellow lights. *Within the text the old characteristic will be described in parenthesis.* Until the conversation

program is completed mariners should be familiar with both systems and alert to the fact that changes may not be immediately reflected in published charts. All changes in aids to navigation will be published in the U.S. Coast Guard's *Local Notice to Mariners* and, where appropriate, the DMAHTC weekly *Notice to Mariners*. Illustrations of the Modified U.S. Aids to Navigation System is shown in appendix Y.

Colors. When proceeding from seaward:

(a) Green (black) buoys mark the port side of channels, or the location of wrecks or obstructions which must be passed by keeping the buoys on the left hand.

(b) Red buoys mark the starboard side of channels, or the location of wrecks or obstructions which must be passed by keeping the buoy on the right hand.

(c) Red and green (black) horizontally banded preferred channel buoys mark junctions or bifurcations in the channel, or wrecks or obstructions which may be passed on either side. If the topmost band is green (black), the preferred channel will be followed by keeping the buoy on the port hand. If the topmost band is red, the preferred channel will be followed by keeping the buoy on the starboard hand.

(d) Red (black) and white vertically striped safe water buoys mark the fairway or mid-channel.

Shapes. In order to provide ready identification certain unlighted buoys are differentiated by shape.

(a) Red buoys, or red and green(black) horizontally banded buoys with the topmost band red are conical shaped and called nun buoys.

(b) Green(black) buoys, or green(black) and red horizontally banded with the topmost band black are cylindrical shaped and called can buoys.

(c) Red(black) and white vertically striped buoys are spherical shaped buoys. Lighted buoys, sound buoys, and spar buoys are not differentiated by shape to indicate the side on which they should be passed. No special significance is attached to the shape of these buoys, their purpose being indicated only by the

color, number, or light characteristics. However, safe water buoys will eventually be fitted with a spherical red and white vertical striped topmark to aid in the buoy identification.

Number. (a) All solid colored buoys are numbered, the red buoys bearing even numbers and the green(black) buoys bearing odd numbers for each increasing from numbers where required.

(b) No other color buoys are numbered; however, any color buoys may be lettered for the purpose of identification.

Light colors. Red(or white) lights on buoys are used only on red buoys or red and green(black) horizontally banded buoys with the topmost band red. Green(or white)lights on buoys are used only on the green(black) buoys or green(black) and red horizontally banded buoys with the topmost band green(black). White lights may be used only on " safe water" aids which show a Morse characteristic.

Light rhythmics. (See Page 192&193). (a) Lights on red buoys or green(black) buoys, if not occulting or isophase, will generally be regularly flashing. For ordinary purposes, the frequency of flashes will be not more than 50 flashes per minute (single flashing). For purposes when it is desired that lights have a distinct cautionary significance, as at sharp turns or sudden constructions in the channel, or to mark wrecks or dangerous obstructions, the frequency of flashes will be not less than 50 flashes but not more than 80 flashes per minute (continuous quick).

(b) Lights on preferred channel buoys will show a series of grouped flashes, specified in number with successive groups in a period having different number of flashes—composite group flashing (or a quick light in which the sequence of flashes is interrupted by regularly repeated eclipses of constant and long duration—interrupted quick flashing).

(c) Lights on safe water buoys will always show a white Morse Code "A" (Short – Long) flash, this combination recurring at the rate of about eight times per minute.

Daylight controls. Lighted buoys are equipped with a special device which automatically controls the electric current to the light. This device causes the light to operate during hours of darkness and to be extinguished during daylight hours. These devices are not of equal sensitivity, therefore all lights do not come on or go off at the same time.

(Mariners should ensure correct identification of aids during twilight periods when some lighted aids to navigation are on while others are not.)

Reflective material is placed on buoys to assist in their detection at night by use of a searchlight. The color of the reflective material agrees with the buoy color. Green reflective materials is placed only on green(black) buoys, red reflective material is placed only on red buoys. Red or green reflective material will be placed on preferred channel (junction) buoys; red if topmost band is red or green if topmost band is green(black). White reflective material on buoys with lateral significance is limited to use on safe water (fairway) buoys. Special purpose buoys (which have no lateral significance) display yellow(white) reflective material. Warning or regulatory buoys display orange reflective horizontal bands and warning symbol, and intracoastal waterway display a yellow reflective horizontal strip in addition to red or green reflective material coincidental to the buoy color.

Special purpose buoys. (a) Buoys for special purposes are colored yellow (white buoys mark anchorage areas; white buoys with green tops are used in connection with dredging and survey operations; white and black horizontally banded buoys mark fish net areas). White and international orange buoys either horizontally banded or vertically striped, are for warning or regulatory purposes to which neither the lateral system nor the other special purpose colors apply.

(b) The shape of special purpose buoys has no significance. They are not numbered, but may be lettered. They display a yellow(amber or white) color light with fixed or slow flash characteristics preferred.

Buoys marking wrecks. Buoys established by the Coast Guard to mark wrecks are generally placed on the seaward or channel side of the wreck and as near to the wreck as conditions will permit. Caution must be exercised when navigating in the vicinity of buoys marking wrecks because, due to sea action, the wreck may shift in location between times that the buoy is established and later checked and serviced.

Station buoys. Buoys are sometimes placed in close proximity to a floating aid to mark the station in case the regular aid is accidentally shifted from station. Station buoys are colored and numbered the same as the regular aid to navigation.

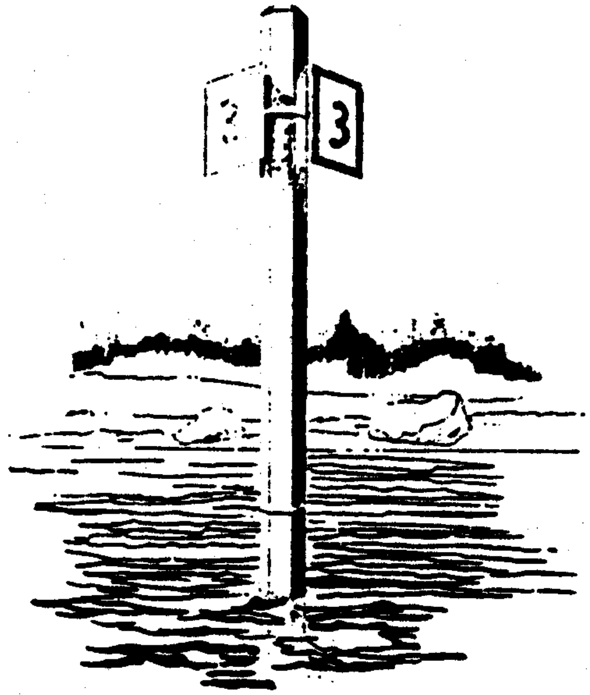
Certain aids to navigation may be fitted with, or have incorporated in their design, radar reflectors designed to enhance their ability to reflect radar energy. In general, these reflectors will materially improve the aids for use by vessels equipped with radar.

Beacons are fixed aids to navigation placed on shore or on marine sites. If unlighted, the beacon is referred to as a daybeacon. A daybeacon is identified by its color and the color, shape, and number of its daymark. The simplest form of daybeacon consists of a single pile with a daymark affixed at or near its top (see the following figure).

Daybeacons may be used instead of range lights to form a range.

Daymarks serve to make aids to navigation readily visible and easily identifiable against viewing backgrounds. For example, the distinctive color pattern and shape of a lighthouse aid identification during the daytime as does the color and shape of a buoy. The size of the daymark that is required to make the aid conspicuous depends upon how far the aid must be seen. On the structures which don not by themselves present an adequate viewing area to be seen at the required distance, the aid is made more visible by affixing a daymark to the structure. These daymarks have a distinctive shape and color depending upon the purpose of the aid. Most daymarks also display numbers or letters so that the daymarks can be more readily identified as a particular aid. The numbers and letters, as well as portions of most daymarks (and portions of unlighted buoys) are made to be retro-reflective to enhance their illumination by the mariner.

Increasing amounts of information are conveyed by a daymark as the mariner approaches. At the detection distance, the daymark will convey only the information of its existence; it will be just detectable from its background. At the recognition distance, the daymark can be recognized as an aid to navigation. At this distance the distinctive shape or color pattern is recognizable. At the identification distance, when the number or letter can be read, the daymark can be identified as a particular aid.



Daybeacon.

The detection, recognition, and identification distances very widely for any particular daymark depending upon the viewing conditions. This is an inherent limitation of any visual signal but is especially true for passive visual signals which utilize the sun as the source for their signal energy. The reflectivity of the daymark surface varies with the angle of the sun relative to the daymark. This causes the luminance of the daymark to vary. The detection, recognition, and identification distances depend upon the relative difference between the luminance of the daymark and that of the background, the position of the sun relative to the observer, and the meteorological visibility.

Beginning in 1975, a revised system of daymarks was gradually being implemented in the United States. The significant changes include the following:

1. On port side daymarks, green is used in lieu of the colors black or white; green numbers and letters are used.

2. On starboard side daymarks, red numbers and letters are used in lieu of white numbers and letters.
3. On ICW daymarks, a yellow horizontal reflective strip is used in lieu of a yellow reflective border as the marking.
4. On junction daymarks, green is used in lieu of black in the color pattern.

Sound Signals

Sound Signals.—Most lighthouses, light platforms, and some minor light structures and buoys are equipped with sound-producing instructions to aid the mariner in periods of low visibility.

Charts and light lists of the particular area should be consulted for positive identification. Caution: buoys fitted with a bell, gong, or whistle and actuated by wave motion may produce no sound when the sea is calm. Their positive identification is not always possible.

Any sound-producing instrument operated in time of fog from a definite point shown on the charts, such as a lighthouse, or buoy, serves as a useful fog signal. To be effective as an aid to navigation, a mariner must be able to identify it and to know from what point it is sounded.

At all lighthouses equipped with sound signals, these signals are operated by mechanical or electrical means and are sounded during periods of low visibility, providing the desirable feature of positive identification.

The characteristics of mechanized signals are varied blasts and silent periods. A definite time is required for each signal to perform a complete cycle of changes. Where the number of blasts and the total time for a signal to complete a cycle is not sufficient for positive identification, reference may be made to details in the *Light List* regarding the exact length of each blast and silent interval. The various types of sound signals also differ in tone, and this facilities recognition of the respective stations.

Diaphones produce sound by means of a slotted piston moved back and forth by compressed air. Blasts may consist of two tones of different pitch, in which case the first part of the blast is high and the last of a low pitch. These alternate-pitch signals are called " two-tone".

Diaphragm horns produce sound by means of a disc diaphragm vibrated by compressed air or electricity. Duplex or triplex horn units of differing pitch produce a chime signal.

Sirens produce sound by means of either a disc or a cup-shaped rotor actuated by compressed air, steam, or electricity.

Whistles produce sound by compressed air emitted through a circumferential slot into a cylindrical bell chamber.

Bells are sounded by means of a hammer actuated by a descending weight, compressed gas or electricity.

Limitations of sound signals.—Sound signals depends upon the transmission of sound through air. As aids to navigation, they have limitations that should be considered. Sound travels through the air in a variable and frequently unpredictable manner.

It has been clearly established that:

1. Sound signals are heard at greatly varying distances and that the distance at which a sound signal can be heard may vary with the bearing of the signal and may be different on occasion.
2. Under certain conditions of the atmosphere, when a sound signal has a combination high and low tone, it is not unusual for one of the tones to be inaudible. In the case of sirens, which produce a varying tone, portions of the blast may not be heard.
3. There are occasionally areas close to the signal in which it is wholly inaudible. This is particularly true when the sound signal is screened by intervening land or other obstruction, or the signal is on a high cliff.
4. A fog may exist a short distance from a station and not be observable from it, so that the signal may not be in operation.
5. Some sound signals cannot be started at a moment's notice.
6. Even though a sound signal may not be heard from the deck or bridge of a ship when the engines are in motion, it may be heard when the ship is stopped, or from a quiet position. Sometimes it may be heard from aloft though not on deck.
7. The loudness of the sound emitted by a sound signal may be greater at a distance than in the immediate proximity.

All these consideration point to the necessity for the utmost caution when navigating near land in a fog. Mariners are therefore warned that sound signals can never be implicitly relied upon, and that the practice of taking sounding of the depth of water should never be neglected. Particular attention should be given to placing lookouts in positions in which the noises in the ship are least likely to interfere with hearing a sound signal. Sound signals are valuable as warnings but the mariner should not place implicit reliance upon them in navigating his vessel. They should be considered solely as warning devices.

Emergency sound signals are sounded at some of the light and fog signal stations when the main and stand-by sound signal is inoperative. Some of these emergency sound signals are of a different type and characteristic than the main sound signal. The characteristics of the emergency sound signals are listed in the *Light List*.

The mariner must not assume:

1. That he is out of ordinary hearing distance because he fails to hear the sound signal.
2. That, because he hears a sound signal faintly, he is at a great distance from it.
3. That he is near to it because he hears the sound plainly.
4. That the distance from and the intensity of a sound on any one occasion is a guide to him for any future occasion.
5. That the sound signal is not sounding because he does not hear it, even when in close proximity.
6. That the sound signal is in the direction the sound appears to come from.

Intracoastal Waterway aids to navigation.—The Intracoastal Waterway (ICW) runs parallel to the Atlantic and gulf coasts from Manasquan Inlet on the New Jersey shore to the Mexico border. Aids marking these waters have some portion of them marked with yellow as shown in Chart No. 1. Otherwise, the coloring and numbering of buoys and beacons follow the same system as that in other U.S. waterways.

In order that vessels may readily follow the Interacoastal Waterway route where it coincides with another marked waterway such as an important river, special marking are employed. These special markings

are applied to the buoys or other aids which already mark the river or waterway for other traffic. These aids are then referred to as "Dual Purpose" aids. The marks consist of a yellow square or a yellow triangle, placed on a conspicuous part of the dual purpose aid. The yellow square, in outline similar to a can buoy, indicates that the aid on which it is placed should be kept on the left hand when following the Intracoastal Waterway down the coast. The yellow triangle has the same meaning as a nun; it should be kept on the right side. Where such dual purpose marking is employed, the mariner following the Intracoastal Waterway disregards the color and shape of the aid on which the mark is placed, being guided solely by the shape of the yellow mark.

Mississippi River system.—Aids to navigation on the Mississippi River and its tributaries in the Second Coast Guard District and parts of the Eighth Coast Guard District generally conform to the lateral system of buoyage. The following differences are significant:

1. Buoys are not numbered.
2. The numbers on lights and daybeacons do not have lateral significance; they indicate the mileage from a designated point downstream, normally the river mouth.
3. Flashing lights on the left side proceedinf upstream show single green or white flashes while those on the right side show double (group flashing) red or white flashes.
4. "Crossing daymarks" are used to indicate where the channel crosses from one side of the river to the other.

The Uniform State Waterway Marking System (USWMS) was developed jointly by the U.S. Coast and states boating administrators to assist the small craft operator in those state waters marked by participating states. The USWMS consists of two categories of aids to navigation. One is a system of aids to navigation, generally compatible with the Federal Lateral system of buoyage, to supplement the federal system in state waters. The other is a system of regulatory markers to warn the small craft operator of dangers or to dangers or to provide general information and directions.

On a well-defined channel, including a river or other relatively narrow, natural or improved waterway, solid colored red and black buoys

are established in pairs (called "gates"), one on each side of the navigable channel which they mark, and opposite to each other to inform the user that the channel lies between the buoys and that he should pass between the buoys. The buoy which marks the left side of the channel viewed looking upstream or toward the head of navigation is colored all black; the buoy which marks the right side of the channel is colored all red.

On an irregularly-defined channel, solid colored buoys may be staggered on alternate sides of the channel but spaced at sufficiently close intervals to inform the user that the channel lies between the buoys and that he should pass between the buoys.

When there is no well-defined channel or when a body of water is obstructed by objects whose nature or location is such that the obstruction can be approached by a vessel from more than one direction, aids to navigation having cardinal meaning may be used. The aids conforming to the cardinal system consist of three distinctly colored buoys:

1. A white buoy with a red top is used to indicate to a vessel operator that he must pass to the south or west of the buoy.
2. A white buoy with a black top is used to indicate to a vessel operator that he must pass to the north or east of the buoy.
3. A buoy showing alternate vertical red and white stripes is used to indicate to a vessel operator that an obstruction to navigation extends from the nearest shore to the buoy and that he must not pass between the buoy and the nearest shore. The shape of buoys has no significance in the USWMS.

Regulatory buoys are colored white with international orange horizontal bands completely around the buoy circumference. One band is at the top of the buoy with a second band just above the waterline of the buoy so that both orange bands are clearly visible from approaching vessels.

Geometric shapes are placed on the white portion of the buoy body and are colored international orange. The authorized geometric shapes and meanings associated with them are as follows:

1. A vertical open faced diamond shape means danger.
2. A vertical open faced diamond shape having a cross centered in the diamond means that vessels are excluded from the marked area.

3. A circular shape means that vessels in the marked area are subject to certain operating restrictions.
4. A square or rectangular shape indicates that directions or information is contained inside.

Regulatory markers consist of square and rectangular shaped signs displayed from a fixed structure. Each sign is white an international orange border. Geometric shapes with the same meaning as those displayed on buoys are centered on the sign boards. The geometric shape displayed on a regulatory marker is intended to convey specific meaning to a vessel operator—whether or not he should stay well clear of the marker or may safely approach the marker in order to read any wording on the marker.

Private aids to navigation are those aids not established and maintained by the U.S. Coast Guard. Private aids include those established by other federal agencies with prior U.S. Coast Guard approval, those aids to navigation on marine structures or other works which the owners are legally obligated to establish, maintain, and operate as prescribed by the U.S. Coast Guard, and those aids which are merely desired, for one reason or another, by the individual, corporation, state or local government, or other body that has established the aid with U.S. Coast Guard approval.

Before any private aid to navigation consisting of a fixed structure is placed in the navigable waters of the United States, authorization to erect such structure shall first be obtained from the District Engineer, U.S. Army Corps of Engineers, in whose district the aid will be located.

Private aids to navigation are similar to the aids established and maintained by the U.S. Coast Guard, but are specially designed on the chart and *Light List*.

Although private aids to navigation are inspected periodically by the U.S. Coast Guard, the mariner should exercise special caution when using them for general navigation.

Protection by law.—All aids to navigation, including private aids, are protected by law. The *Code of Federal Regulations* (33 CFR 70) refers.

It is unlawful to take possession of or make use of for any purpose, or build upon, alter, deface, destroy, move, injure, obstruct by fastening vessels thereto or otherwise, or in any manner whatever impair the usefulness of any aid to navigation established and maintained by the United States.

Whenever any vessel collides with an aid to navigation established and maintained by the United States or any private aid established or maintained in accordance with 33 CFR 64, 66, 67, or 68, or is connected with any such collision, it shall be the duty of the person in charge of such vessel to report the accident to the nearest Officer in charge, Office of Marine Inspection, U.S. Coast Guard.